Enhancing Collaboration Creating Value: Business Interaction with the UK Research Base in Four Sectors

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Business interaction with the UK research base in four sectors

By Andrea Mina and Jocelyn Probert

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3 September 2012

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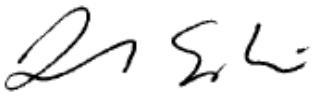
Foreword

This is the third in a series of linked reports on gaining the most value from UK research, and in particular its publicly-funded research. The first report set the UK's spend on R&D in an international context and the second assessed the impact of that expenditure. In this third review, the research team interviewed seventy-one top-level sources from both large and small firms, universities, government/regulators and charities to explore the challenges and opportunities concerning the creation of value through collaboration. Focusing on four different sectors – construction, energy, pharmaceuticals and the converged creative, digital and IT industry – the review reveals the different innovation needs within and across these industries and highlights the main challenges to collaborative innovation that the UK faces to be competitive in the modern global knowledge economy.



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EXECUTIVE SUMMARY:

1. This report explores the challenges and opportunities perceived to characterise knowledge exchanges between business and the UK research base. It focuses on the value chains of four sectors (pharmaceutical, creative-digital-IT, energy and construction) broadly defined, to take into account different aspects of the UK innovation system.

2. The four sectors have very different structures, display varied reliance on R&D, innovate in different ways, work with a range of technology solution clock-speeds and adopt different approaches to collaboration. But there is also great variety within value chains depending on firm characteristics and the nature of their knowledge bases.

3. Guided by prior research and reflecting the themes that emerge from a comprehensive programme of interviews with key decision-makers, we focus on the drivers of R&D location decisions, collaborative R&D, interaction with the public research base, exploitation of academic research, and the challenges and missed opportunities of UK plc in enhancing value through collaboration.

4. Our evidence shows that R&D location decisions are increasingly global, with the availability of talent and quality of research acting as clear drivers of location decisions for science-based businesses. Proximity to markets is especially important for later stages of R&D processes, for less R&D intensive investments and for services. Location of R&D in the proximity of universities is not essential but is seen as increasingly important in R&D intensive businesses.

5. Partnering and externalisation of innovation activities are on the increase because of the growing uncertainty, cost and complexity of technology. Choices of collaborators are flexible, may involve single individuals, teams or whole organisations, and depend on contingent 'fit for purpose' decisions.

6. The propensity to enter collaborative arrangements with universities differs by firm size, with smaller firms at a considerable disadvantage (unless they are connected with the research base from the start), and by sector, with strong interactions in pharmaceuticals but also energy, fewer interactions in CDIT, and the least in construction.

7. Collaboration is a resource-intensive activity, but financial resources represent only part of the exchange between industry and the research base. Importantly, successful collaborations rely on investments in the time spent on joint work and the exchange of ideas, materials or tools. Of the essence are: the development of an understanding of the institutional framework in which partner organisations operate; shared vision of the objectives of the collaboration; and trust, clarity of motives and transparency in its conduct.

8. Businesses and academia operate with different objectives and timeframes. Academic incentives, e.g. promotion criteria, are still built around publications and grant proposals rather than industry collaborations or industry experience. This hinders labour mobility between industry and academia even where industry expertise would be needed in research, education or commercialisation activities.

9. Overall, the culture of university-industry collaboration in the UK has improved considerably, if unevenly, across different organisations or divisions thereof. Emergent trends include the rationalisation of relationships (selection of a smaller number of high quality interactions) and their increased formalisation (in the interest of limiting the time and effort required to establish agreements).

10. Critical barriers to commercialisation of academic research involve management of intellectual property rights, financial constraints, lack of business know-how and low propensity to risk.

11. From the viewpoint of business, universities tend to lack strategic focus in their patenting activities and to privilege quantity (as an output metric) over quality of instances of technology transfer. Negotiations over IP can be unduly lengthy, not least owing to fundamental disagreements over value. However, many companies (typically the larger and more experienced firms) also report that they have no particular problem reaching agreement on IP.

12. A barrier to innovation emerging with some regularity is shortage of finance, attributed at least in part to the current macroeconomic framework. Nevertheless, it is noted that a lack of entrepreneurial finance is not related to a general lack of capital in the system but rather to poor appetite among investors for risk financing.

13. Barriers to the exploitation of academic research include the low propensity to risk of university researchers and their lack of business know-how. There are, however, indications that younger academics are less risk-averse.

14. Despite overall positive views on the prospects for university-industry interactions, some concerns exist that perceived pressures on universities to demonstrate the value of their work to the commercial world can have unintended consequences, for example on the patient, long-term accumulation of fundamental knowledge.

15. With specific reference to the four sectors, a key challenge for pharma companies is the renewal of the industry's research and business model. The sector is increasingly externalising R&D that was previously done in-house. Higher levels of outsourcing and collaborations bring with them more opportunities for independent R&D providers, smaller firms and universities. The complementary challenge is the growth of a dynamic and well-supported biotech community in the UK, with potential for strong contributions from entrepreneurial academic teams.

16. In CDIT, key challenges are the need to improve the skills level of graduates, modernise the business model of the many small and disconnected firms (including new approaches to IP and value generation), and develop an outward-facing approach to the digital economy. Up-skilling and an increase in the supply of human capital are also called for in the energy sector, combined with the need for a stable policy framework and strong signals from government which would release investments in innovation. In construction, where we register the least amount of collaborative work with the research base, innovation is hindered by excess fragmentation of the value chain, risk aversion, and severe limits to the demand for innovation despite a recognised need to upgrade the value chain and intensify the use of innovative solutions.

17. There appear to be a number of missed opportunities for UK plc.

18. Willingness to invest in UK-based research is sensitive to the government policy agenda and a business-friendly operating environment. But risk aversion among public-sector officials and the perceived weakness of government in formulating coherent long-term strategies challenge the ability of businesses to implement long-term investment plans.

19. The UK is less supportive of home-grown technologies relative to comparable advanced economies, with serious consequences for the competitive advantage of the UK innovation system and its capacity to generate value from its research investments.

20. In universities, a 'silo' mentality discourages inter-disciplinarity and may hinder the ability to address the 'grand challenges' of the future (e.g. smart cities, climate change) as has been recognized by cross-disciplinary initiatives supported by the Research Councils, the Higher Education Funding Councils and the Technology Strategy Board. Moreover, despite current efforts and considerable variations across areas and organisations, collaboration with SMEs remains a challenge.

21. While the higher education sector is in many disciplines second to none by international standards, there is concern over the inadequate supply of talented young people with strong STEM backgrounds and/or state-of-the-art technical training. In addition, the UK's entrepreneurial aspirations remain more modest than the country's stock of intellectual capital would imply.

22. While views of the relative attractiveness of the UK for R&D investment remain very positive – despite variations across industries linked to the different long-term performance of UK manufacturing sectors – investments in skills made by emerging economies and R&D incentives schemes offered by their governments are potential game-changers and leave no room for complacency.

23. We conclude that there are general challenges across sectors for the UK knowledge-based economy but it is equally clear that a 'one-size-fits-all' policy approach would be far too simplistic. Efforts to promote, develop, incentivise and support innovation value chains through knowledge collaboration and industrial strategy must reflect their underlying needs and future competitive challenges.

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1. Introduction

1.1 Motivation and objectives

The problem of generating wealth from knowledge has been central to recent academic and policy debates on the structure and dynamics of advanced economies. There are multiple mechanisms through which new knowledge can be generated, diffused and applied to productive uses in the economy. And there are marked differences in the practices, incentives and behaviours that are observed across countries, sectors and organisations in relation to these aims.[i] In recent years the perception has been growing that technical change is increasingly complex, modular and globalised. In addition, stronger international competition and higher costs of R&D seem to have intensified the fundamental uncertainty associated with investments in innovation.

This has motivated the diffusion of more 'open' models of innovation and led to significant changes in the role of higher education institutions.[ii] These changes are associated with the concomitant, if uneven, development of new ways of organizing the provision of external capital, the emergence of advanced intermediate markets for knowledge and the creation or transformation of institutional channels dedicated to the transfer of technological knowledge. Even though collaborations, alliances or more generally 'systemic' connections have long been recognized as important for successful innovation[iii], interactions between businesses and universities are sources of increased expectations because of their potential direct and indirect contribution to the competitiveness of innovation systems.[iv]

These interactions are the focus of this study, the last of a set of three CIHE reports that look into the problem of enhancing the value generated from the UK research base. The first report explored the UK R&D landscape (Hughes and Mina, 2011) through an analysis of official statistical sources on R&D activities. It found that despite increases in investment in higher education research, there is an R&D funding gap between the UK and its major industrial competitors. Furthermore, R&D is highly concentrated in the UK's biggest firms with only 3.5% of R&D being conducted by independent SMEs in 2011. Finally, the UK innovation system is simultaneously open and vulnerable: overseas investment in UK R&D is very high by international standards, a clear sign of the attractiveness of the UK as a location for R&D, but this openness also means that the country is relatively vulnerable to strategic investment decisions made outside the UK.

The second report (Hughes and Martin, 2012) reviewed and discussed existing evidence on the impact of publicly-funded R&D on the UK's economy, firms and society. It established that quantification is exceptionally difficult and attempts to reduce multiple inputs to a single rate of return often require heroic assumptions. Secondly, that successful public-sector impact most often relies on complementary private and charitable sector investment. And finally that policy must be shaped by a systems view of impact, rather than by a simple linear model. Rate of return calculations provide little policy guidance and intermediate and

trajectory-based measures must be developed that focus on the interactions within the innovation system.

This third report builds on its predecessors and adds original qualitative evidence on the interaction between companies and the UK public research base.[v] Its aim is to highlight certain strengths and weaknesses, and challenges and opportunities, by focusing on the innovation value chains of four sectors of the economy that are characterised by different patterns of R&D and innovation.[vi] These are the pharmaceutical, energy, creative-digital-IT (CDIT) and construction sectors.

In this report we present new evidence on several key aspects of the interaction between businesses and the UK research base. Guided by prior research, we report on the themes that have emerged from a comprehensive programme of interviews with key decision-makers. After a background section on the specific sectoral contexts (Chapter 2), we address: the choice of locations for R&D investments (Chapter 3); patterns of collaborative R&D (Chapter 4); motivation, characteristics and sources of attrition in university-industry interactions (Chapter 5); the commercialization of academic research (Chapter 6); and the overall challenges and opportunities of working with the research base (Chapter 7). We then conclude with a summary of our main findings (Chapter 8).

1.2 Methodology

The primary evidence for this report is drawn from a wide-ranging programme of interviews with key informants in each of the four innovation value chains – pharmaceuticals, CDIT, energy and construction – grounded in semi-structured questions around corporate research and industry-university collaboration. We also draw on recent industry and government reports to inform our interview protocols and to provide background information on the sectoral contexts presented in Chapter 2.

The four sectors were selected by the *Enhancing Value* Working Group of CIHE for their relevance to the UK economy and the diversity of their innovation patterns. The objective of providing a nuanced picture of the challenges and opportunities that characterise interactions with the UK research base called for a qualitative research design. The first step was to explore the specificities of sectoral contexts, develop a pro-forma interview and select a sample of interviewees with in-depth knowledge of different aspects of the four innovation value chains.

The CIHE secretariat, guided by the *Enhancing Value* Working Group of the Council, arranged a one-hour teleconference between the research team and four top level sources from the pharmaceutical industry in November 2011 as well as scoping workshops on the CDIT sector (five participants) in December 2011 and on the energy sector (six participants) in March 2012. These workshops each lasted for two hours. For the construction sector we

conducted three in-depth scoping interviews, lasting approximately one hour each, between December 2011 and January 2012. This scoping phase of the research served the purpose of identifying relevant subtopics, key informants and additional secondary literature. All these meetings were recorded and later transcribed.

For the main data collection exercise, which extended over the four-month period January to April 2012, we first interviewed the contacts proposed during the scoping phase. They included workshop participants who agreed to make themselves available for individual in-depth interviews and in some cases their colleagues, as well as senior executives in third-party organisations (businesses and universities). A meeting of the CIHE Working Group on 14 March 2012 generated additional high-level contacts. Using a mixed strategy of direct selection and the snowballing technique of asking the interviewees themselves for further contacts that could inform us on other exemplary cases, we obtained a final sample (including the three in-depth scoping interviews for construction) of 71 senior-level participants across the four sectors (see Table 1). Interviewee organisations were stratified as follows: large firms (20), SMEs (16), universities (7), government/regulators (6), and a broader category of charities, foundations and independent observers (8).

Interviews ranged in length from 30 minutes to 90 minutes, with an average of approximately 50 minutes. Participants were assured anonymity of quotes to encourage frank discussion. As was the case for the scoping workshops, all interviews were recorded and transcribed in full. The authors coded the interviews independently of each other, with no major discrepancy between outcomes. In the treatment of the representative quotes that are included in the report, references that could lead to identification of the source have been removed and commercially sensitive information has been omitted. The key findings of the study are organised by emergent themes and presented in Chapters 3-7. Table 1 contains the full list of interviewees.

Table 1: Interview Sample

Organisation	Name	Position
ABB Automation	Juergen Kappler	Global Technology Manager
ABB Group Measurement Products	Sean Keeping	VP Technology
ARUP	Jeremy Watson	Director Global Research
ARUP/University of Cambridge	John Miles	ARUP/RAE Research Professor
Astex Pharmaceuticals	Harren Jhoti	President
AstraZeneca	Martin Mackay	President R&D
AstraZeneca	Mene Pangalos	Executive VP, Innovative Medicines
Atkins	Keith Clarke	Director of Sustainability (ex-CEO)
Autonomy	Andrew Kanter	Chief Operating Officer
BBC	Ralph Rivera	Director of Future Media
BBC	Matthew Postgate	Controller, BBC Research & Development
BBC	Daniel Pike	Head of Technology Transfer, R&D
BP Institute Cambridge	Andy Leonard	Vice President
Breathing Buildings	Shaun Fitzgerald	Managing Director
BSkyB	Emma Lloyd	Director of Emerging Products
BT Innovate & Design	Jonathan Legh-Smith	Head of Partnerships & Strategic Research
BT Innovate & Design	John Seton	Head of Regional Strategic Engagements
Cabinet Office, Major Projects Authority	David Pitchford	Executive Director
Cisco	Trevor Warwick	Engineering Director, Network Operating systems
Cisco	Tony Brett	Engineering Director, Telepresence Technology Group
Convergence Pharmaceuticals	Clive Dix	Chief Executive Officer
Costain	Bill Hewlett	Technical Director
Costain	Darren James	MD Infrastructure
Costain	Phillip Russell	O&M Capability Director
Department of Health	Sally Davies	Chief Medical Officer
Digital TV	Simon Gauntlett	Technology Director
Double Negative	Alex Hope	Managing Director
Eidos/Square Enix	Ian Livingstone	Life President, Eidos
Energy Technology Partnership	Simon Puttock	Executive Director
Ensus/Libertine	Sam Cockerill	Business Development Director
GSK	Dave Allen	SVP, Respiratory Therapy Area
GSK	Ian Tomlinson	SVP, Biopharm R&D and Worldwide Business Development
GSK	Patrick Vallance	President R&D
GSK	Malcolm Skingle	Director, Academic Liaison Medicines Discovery and Development
Heptares	Malcolm Weir	Chief Executive Officer
Hill & Smith	Richard Endersby	Special Projects
HP Labs	Nick Wainwright	Director of Open Innovation, Europe
Huntingdon Life Sciences	Paul Brooker	Director, UK Operations

Imperial College	David Gann	Professor and Deputy Principal, Research & Business Engagement
Imperial College	David Fisk	Laing O'Rourke Chair in Systems Engineering and Innovation Research
Intelligent Energy	Henri Winand	Chief Executive Officer
Joulevert	Colin Matthews	Green Fuels Adviser
LaunchPoint	Stuart Deed (ex-SSE)	Managing Director
Medical Research Council	Declan Mulkeen	Director, Research Programmes
Mozilla Foundation	Mark Surman	Executive Director
National Nuclear Lab	Paul Howarth	Managing Director
National Nuclear Lab	Andy Elsden	Strategy & Planning Director
Neusentis (Pfizer Cambridge)	Devyn Smith	Chief Operations Officer
Nuclear Decommissioning Authority	Darrell Morris	Research Manager
Olympic Delivery Authority	Sir John Armitt	Chairman
Pelamis Wave Power	Richard Yemm	Director and Founder
Pfizer	Annette Doherty	SVP and Sandwich Site Leader
PRP Architects	Andy von Bradsky	Chairman
Rolls Royce	Richard Swinburn	Head of Technology
Sainsbury	Paul Crewe	Head of Sustainability, Engineering, Environment and Energy
Shell	Ed Daniels	Executive VP, Projects & Technology
Siemens Industrial Turbomachinery, Energy Sector	Steve Middlebrough	Director, Service Engineering
Siemens Industrial Turbomachinery, Energy Sector	Ulf Linder	Director, Product Development
SV Life Sciences	Graham Boulnois	Partner
Tarmac	Nick Toy	National Business Development Mgr
Tarmac	Nizar Ghazireh	University Liaison
Telefonica Europe	Mike Short	Vice President
TSB	Derek Allen	Lead Technologist, Energy
TSB/MediaClarity	Jeremy Silver	Creative Industries, Lead Specialist
University of Manchester	Nancy Rothwell	President and Vice-Chancellor
University of Cambridge	Robert Mair	Professor, Head of Civil and Environmental Engineering
University of Dundee	Pete Downes	Professor, Principal and Vice-Chancellor
University of Reading	Roger Flanagan	Professor, School of Construction, Management and Engineering
Virgin Media	Ian Mecklenburgh	Director, Consumer Platforms
Wellcome Trust	Ted Bianco	Director, Technology Transfer
Wired Sussex	Phil Jones	Managing Director
	Roland Brown	Consultant

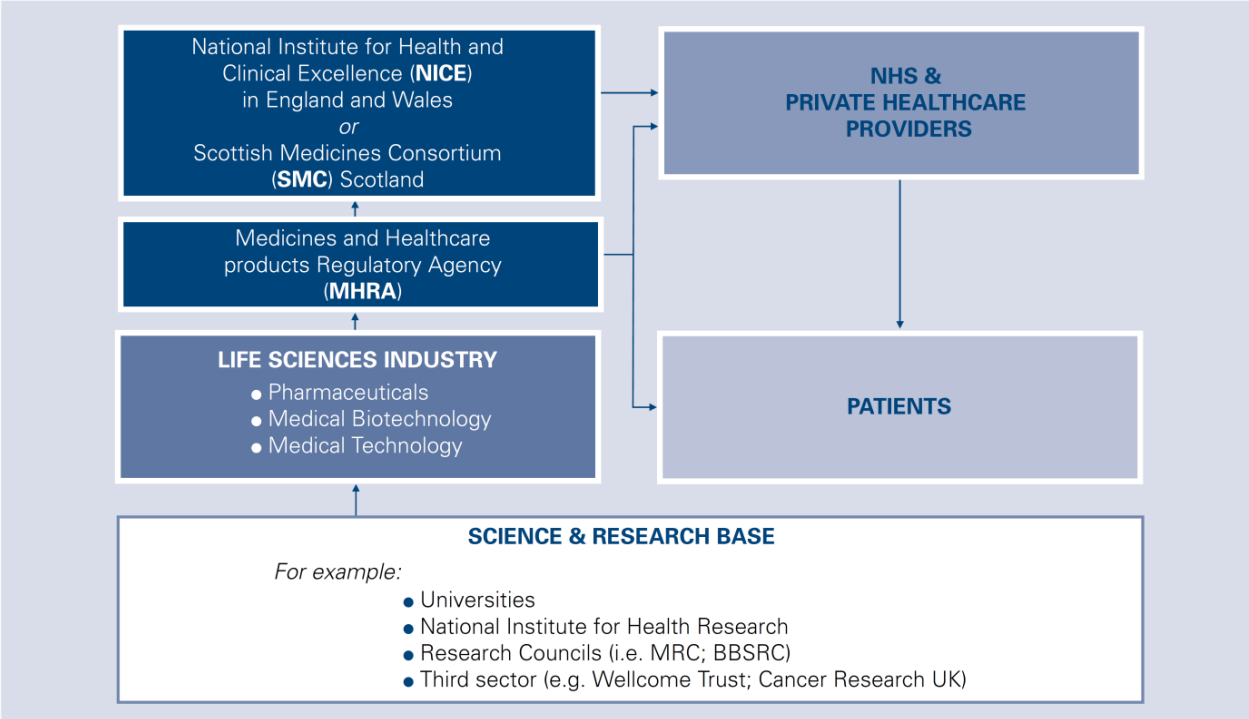
2. Context

2.1 Pharmaceuticals

The pharmaceutical sector is one of the most important components of the UK economy. It includes more than 350 companies with a combined turnover in excess of £30bn and employment of more than 75,000 people. The sector is highly concentrated with less than 20 percent of all companies employing nearly 90 percent of the total workforce and with the top 37 companies accounting for approximately 83 percent of total turnover in the sector. Pharmaceutical firms are responsible for nearly 30 percent of the total R&D expenditure of the UK economy. The UK has two of the top five companies in the world (in terms of share of total sales) and hosts sites of approximately two thirds of the top fifty global pharmaceutical companies (HM Government, 2011).

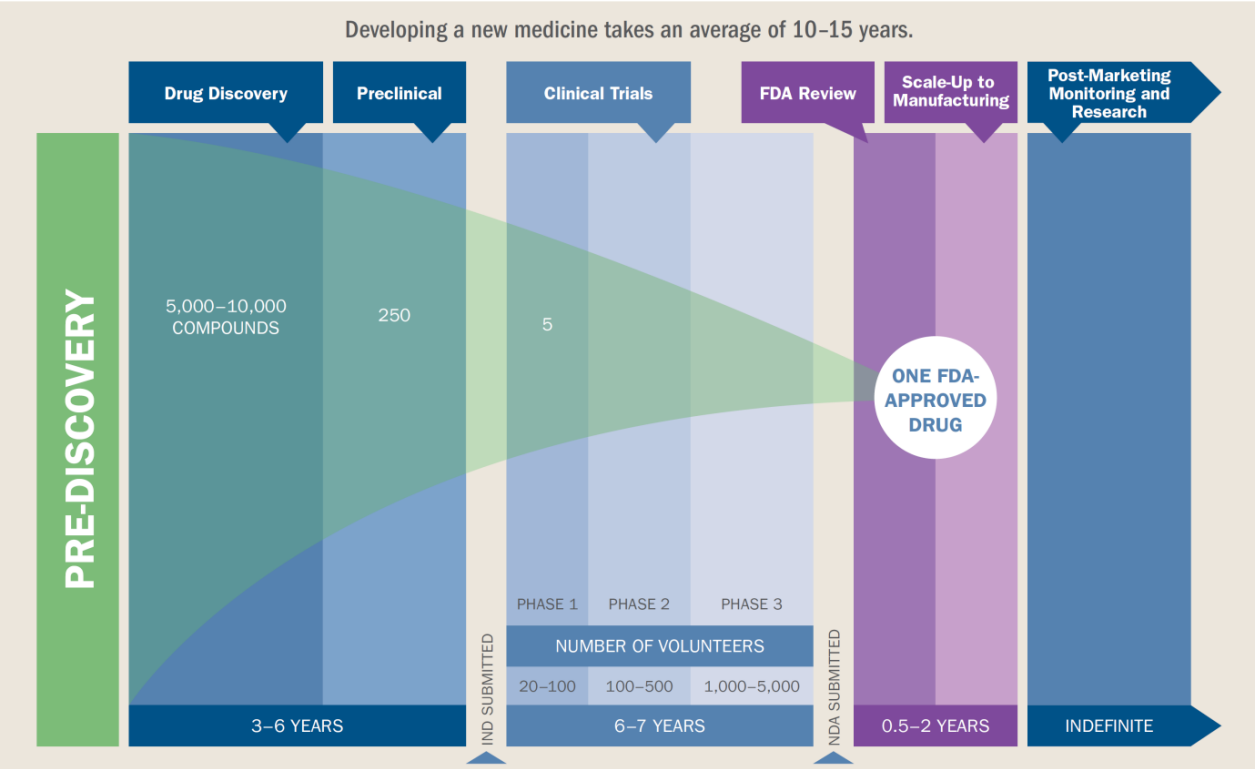
The sector is an integral part of the Life Sciences market and of the innovation system associated with it. This includes businesses (pharmaceutical, biotechnology and medical devices), regulators, health service providers and patients, and has distinctively strong connections with the science base and a very prominent charitable sector (Figure 2.1).

Figure 2.1: Structure of the Life Sciences Market in the UK



Source: UK Department for Business, Innovation and Skills (2010)

Figure 2.2: The Research and Development Process



Source: PhRMA (2011)

In synthesis, innovation in the pharmaceutical sector can be characterised as follows (BIS, 2010):

- Long lead development times for new products (Figure 2.2)
- High levels of risk and uncertainty
- High R&D intensity
- High development costs
- Strong regulation of processes and demand

After decades of strong performance and expansion, the sector has recently undergone a phase of consolidation and change. The 'blockbuster' model of drug discovery which underpinned a phase of sustained growth until the end of the 2000s reached a turning point around the beginning of the new century. It is about this time that the limits of the fully integrated, large scale, and broad model of pharmaceutical R&D started to become evident despite the emergence of new market opportunities (among them, ageing populations) and continuous advancements in basic scientific understanding. The expiry of key patents, coupled with increased overall R&D costs, decreasing R&D productivity, tougher regulation (including price levels deemed acceptable in monopsonistic markets), and shorter exclusivity periods for intellectual property rights, have placed the sector under considerable strain. Even though it has opened up access to remote markets, globalisation has also changed the

relative costs and benefits of some activities and exposed established manufacturers to increased competition from countries with low production costs.

The move from a blockbuster model to personalised medicine has implied a re-organisation of the structure and management of intra-mural R&D and the development of strategies to de-risk drug development, to focus investments, to increase the degree of R&D outsourcing and to broaden and intensify co-operation with external partners. On the one hand, this has implied a new role for younger and smaller (primarily biotech) firms. On the other, it has generated stronger emphasis on collaborative work with universities and the public research base at a time when expectations are also growing on the higher education sector to maximise the impact of its research.

A recent report on university-industry collaborations in the biomedical sector shows the strength of the UK performance (Marsten, 2011). On a global scale, biomedical research authored or co-authored in the UK achieves relatively high impact when it is measured in terms of citations (the value of this metric is higher for the UK than for the US). The share of publications jointly produced by industry and academia ranks second in the world and industry funds ten percent of biomedical research in the higher education sector. However, the report also notices that compared to other countries (for example, Germany) private-sector investments in UK universities have marked time, and as a share of universities' total external research funding the industry's contribution has been in decline. While the strength of the research base is seen to attract private R&D investments, this has not prevented the recent closure of high-profile research sites (for example at Sandwich and Harlow). In addition, the share of early-stage clinical trials performed in the UK – the segment of the experimentation process where excellence in research should be especially important – is falling. The position of the UK relative to other countries is strong, but competitors appear to be closing the gap quickly.

2.2 Creative Digital and IT

The grouping of Creative, Digital and Information Technology businesses into a single sector reflects the increasingly digitalised nature of the creative industries as well as technological and business model convergence in formerly relatively stable and separate industry categories. The CDIT definition embraces firms that create media content and build applications through to those that supply IT infrastructure and provide IT services. In the absence of a single industry classification (the former Creative Industries alone covered thirteen industrial categories) we rely on CIHE estimates of the sector's economic contributions: CDIT contributes 12% of Gross Value Added to the UK economy and provides work for over 2.5 million employees and freelancers (CIHE, 2010). This makes it a larger provider of work in the UK than even the construction industry. It is also a significant contributor to the UK's balance of payments: collectively the Creative Industries accounted for 10.6% of UK exports in 2009 (DCMS, 2011), through the international sale of products

such as TV and radio content, videogames and film visual effects. The creative industries as a whole function in increasingly international markets (Miles & Green, 2008).

Employment in the Creative Media sub-sector since 1997 has grown by 2% per annum, double the rate for the whole economy, but in the Software, Computer Games and Electronic Publishing sub-sector employment growth was 5% per annum (DCMS, 2011), implying that some areas of creative industry have performed much less well. Alongside giants such as the BBC and the UK subsidiaries of global IT firms (e.g. HP, Cisco, Microsoft, Google), many thousands of SMEs or micro businesses co-exist in a rich eco-system. The UK's audiovisual broadcasting and commissioning segment, for example, comprises a diverse business community of over 7,000 firms employing around 132,000 people, while also supporting the wider creative industries (Communications Chambers, 2011). This characteristic tends to encourage a clustering effect around certain hotspots, such as London's Soho for film, post-production and visual effects, London's Shoreditch for digital media, Cardiff for media production (Chapain et al, 2010) and Dundee for videogames. Strength in production of content and applications helps to fuel consumer demand for technologically advanced hardware whilst also stimulating investment in the UK's communications infrastructure. Sources of challenge to the UK's CDIT sector include the off-shoring or out-sourcing of some elements of the production process to lower cost countries – at the risk of losing control over code and/or control over process (Miles & Green, 2008) – and the determination of certain governments to incentivise through favourable policy actions the establishment and growth of knowledge-intensive creative industries in their own countries.

The ability to create and deliver content is highly dependent on advances in IT technologies that may have taken decades to mature. Innovation chains for content and technology thus differ significantly owing to the very different timescales (and often capital investment) required to bring a new product to market. Whereas new content and software can be developed within the space of a few weeks or months, investments in key platform architectures – around silicon (e.g. more powerful and high-speed chips) or optical fibres, for example – typically take decades to mature.[vii] Returns on long-term technology investments do not necessarily accrue to the initial investors, but may have a substantial impact on the broader innovation eco-system. Digitisation, meanwhile, is profoundly transforming the speed of diffusion and the means of delivery of content throughout the CDIT sector.

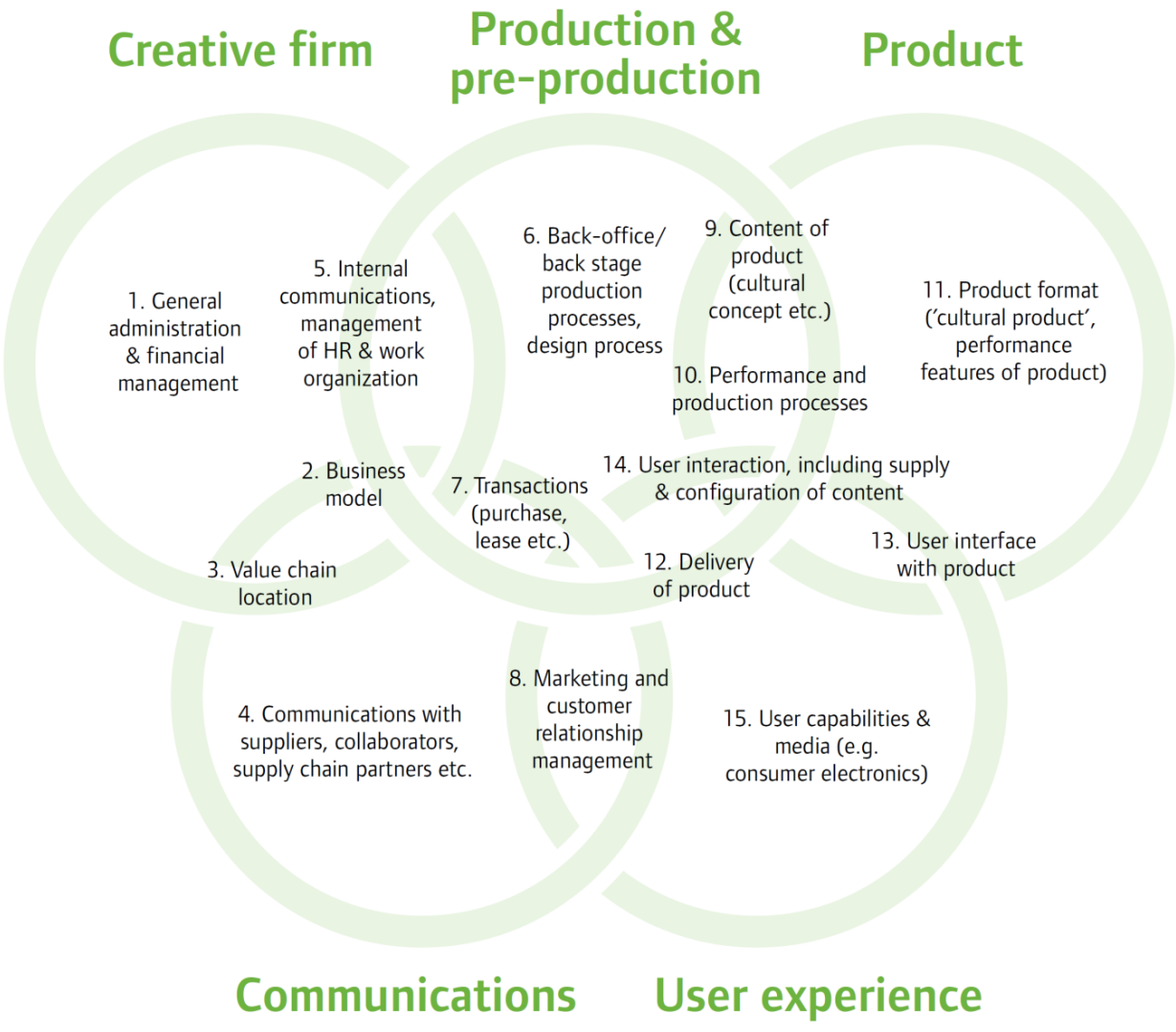
Aside from the dichotomy of timescales between content and technology generators, innovation characteristics of the CDIT sector include (Miles & Green, 2008):

- dependence on a highly-skilled professional labour force
- active user-driven demand
- a high proportion of revenues derived from new products
- inter-firm cooperation and clustering

- active protection of innovations (primarily copyright rather than patent)
- few regulatory impediments and a positive role for industry standard-setting

Innovation in CDIT lies more often in solving current problems on projects than in clearly categorised R&D work. It is an inherent aspect of routine problem-led development processes, rather than an attempt to develop new commercial opportunities in their own right, and is part of the rational response to continual change in the industry (Miles & Green, 2008). Only the largest firms have formal R&D strategies and dedicated research resources. Figure 2.3 (from Miles & Green, 2008) indicates the different interfaces where innovations can take place in the creative industries and which – in common with other service industries – include consumer experience and co-production activities. Much of this innovation in CDIT firms is not measurable for official statistical purposes.

Figure 2.3: Sites of Innovation in the Creative Industries



Source: Miles & Green (2008)

Digitisation has accelerated sector fragmentation and, combined with market and technological dynamism, has increased the need for collaboration (Mateos-Garcia & Sapsed, 2011). But such partnering typically occurs between businesses rather than with the university sector. CDIT businesses look to absorb from the UK's public research base a wide range of academic disciplines, ranging from science, engineering and computing skills through to the arts and humanities skills more commonly associated with 'creative' activity, and they attempt to influence course content through the provision of guest lectures and other teaching-related interactions with students. But there is rather little evidence of industry turning to universities for research inputs, suggesting greater scope in the future for knowledge transfer via strategic partnerships (Miles & Green, 2008).

2.3 Energy

The energy sector directly employs 173,000 people, equivalent to 7 percent of UK industrial employment, and accounts for 3.9% of GDP. In addition it indirectly employs hundreds of thousands more engaged in support activities, for example, related to offshore oil and gas exploration. Crude oil and oil product exports contribute to the balance of payments, although the UK has been a net overall importer of energy since 2005. Transport, the biggest single user of energy, accounted for 37% of final energy consumption in 2010. Reflecting decline in energy-intensive industrial activity in the UK, the share of industrial consumption is just 18%, while households are responsible for 32% of final energy use (DECC, 2010).

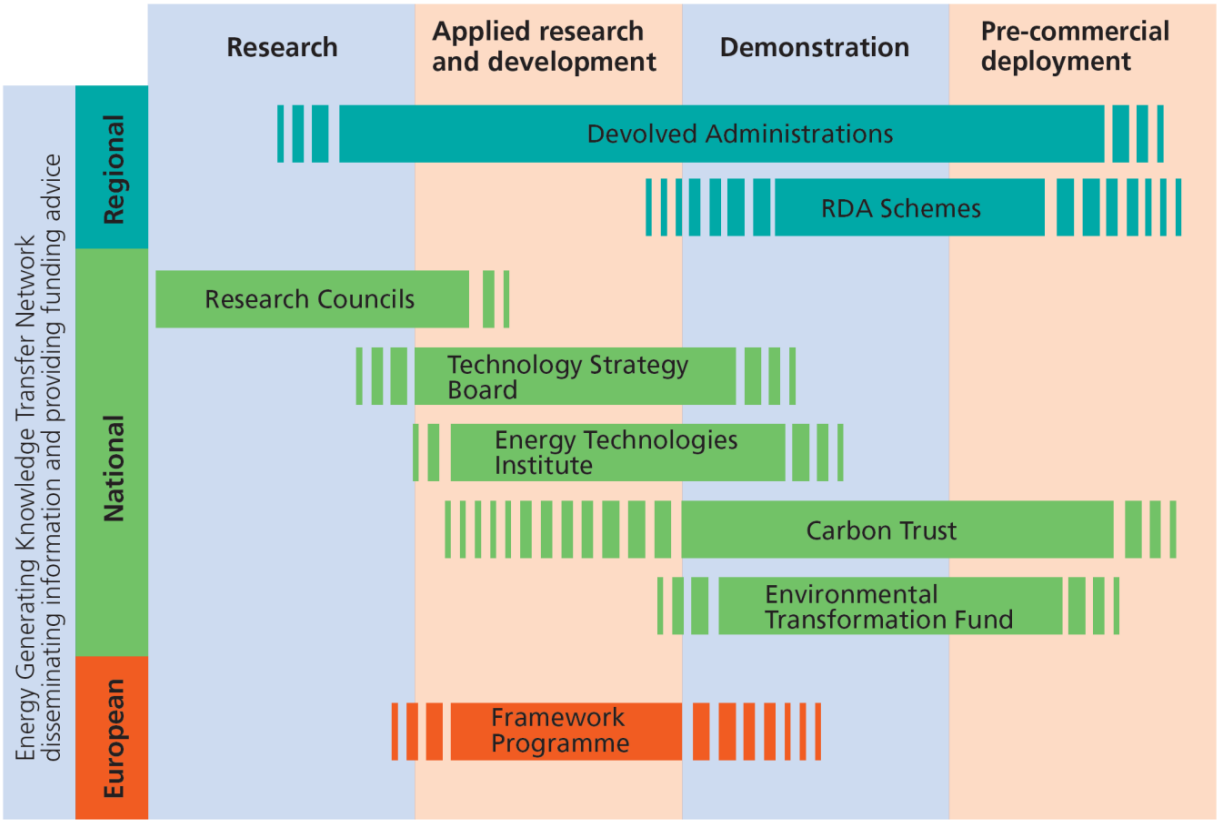
Government energy policy is shaped by legislation. The Climate Change Act 2008 requires a 34% reduction in greenhouse gas emissions by 2020 and an 80% reduction by 2050. Meanwhile, the EU Renewable Energy Directive obligates the UK to generate 15% of total energy needs from renewable sources by 2020. These twin demands stimulate research to reduce UK dependence on fossil fuels, which for electricity generation capacity remains high: gas turbines supply 45% of UK electricity and coal 28% – with nuclear power generating 16% and renewable sources currently producing 6.8% of requirements. Market concentration in electricity is such that six vertically integrated energy companies dominate both generation (where they occupy a 67% share) and the retail supply segment (99% share of domestic supply) (DECC, 2010).

R&D investment by the electricity supply industry since liberalisation in 1990 has fallen, particularly in the transmission segment, accelerating the decline already seen in government R&D prior to the reforms (Jamasb & Pollitt, 2011). Privatisation led to the loss of the Central Electricity Generating Board laboratories, the British Gas research laboratory and the coal research laboratories (RCUK, 2010 p.22). Industrial R&D (£469 million in 2009) is now primarily directed to petroleum product refining and the processing of nuclear fuels (DECC, 2011). The public research budget (USD407 million in 2009) is half the size of Germany's on a per capita basis and one-third that of France (RCUK, 2010). Although a

diverse array of renewable energy technologies is under development to help to meet the sector's decarbonisation targets, the UK's efforts to meet national energy objectives have been described as inadequately funded and too fragmented to achieve critical mass (RCUK, 2010).

Knowledge exchange between the energy industry and the public research base is well-established, through groupings such as ETI (Energy Technologies Institute) – where applied research and demonstrations are carried out – as well as through bilateral arrangements between companies and universities (RCUK, 2010). Funding mechanisms to support research from pre-commercial development Technology Readiness Levels (TRL) 1-2 onwards include the Research Councils, the Technology Strategy Board, the Energy Technologies Institute, and EU Framework Programmes, in addition to national funds such as the Carbon Trust and the Environmental Transformation Fund (Figure 2.4). Industry involvement ensures communication to the academic community of business sector needs, but contact between academia and policy makers appears more limited (RCUK, 2010).

Figure 2.4: Energy-Related Research Funding, TRL levels 1-2 through to early deployment



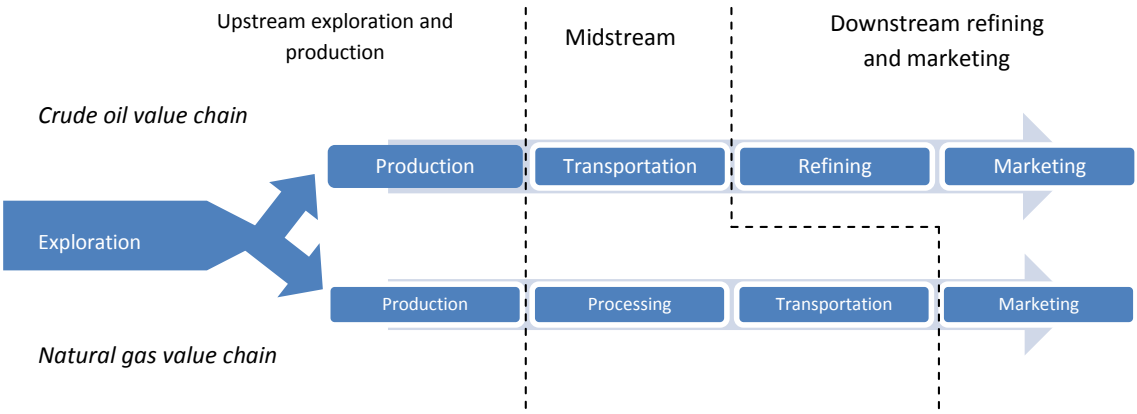
Source: RCUK (2010)

Note: Regional development agencies have been replaced by local enterprise partnerships (LEPs).

Although only relatively small investors in internal R&D, utilities companies are major acquirers and users of external R&D and external knowledge, and buyers of equipment and machinery through their supply chains.[viii] Different types of energy depend on different infrastructure supply chain configurations, each involving different knowledge bases and varying levels of innovation.

Upstream exploration and development of fossil fuels (oil and gas), for example, demand heavy investments in infrastructure as well as constant technological advances to overcome the inherently risky challenges of every project. Drilling appraisal wells is costly and the failure rate is high. Lead time from initial exploration through to full-scale production can be very long owing to the geological and seismic problems presented by each project. Competitive advantage within the industry depends on technical expertise, risk management skills and project control, combined with broad operating experience and continuous investments in technology (Tordo et al., 2011). Downstream refining of crude oil – into products such as fuel oil, gas oil, jet/kerosene, gasoline, naphtha, and liquefied petroleum gases (LPG) or its transformation into feedstock for the petrochemicals industry – also requires substantial investment in capital equipment, but is relatively less demanding in terms of technology requirements. Importantly, many oil companies are involved not only in the production of gas, but also in its processing and marketing (Figure 2.5). Fossil fuel value chain activities are closely interlinked, within or across individual firms as well as within or across national boundaries, and they draw on the expertise of many offshore service supply companies.

Figure 2.5: Fossil Fuel Value Chain

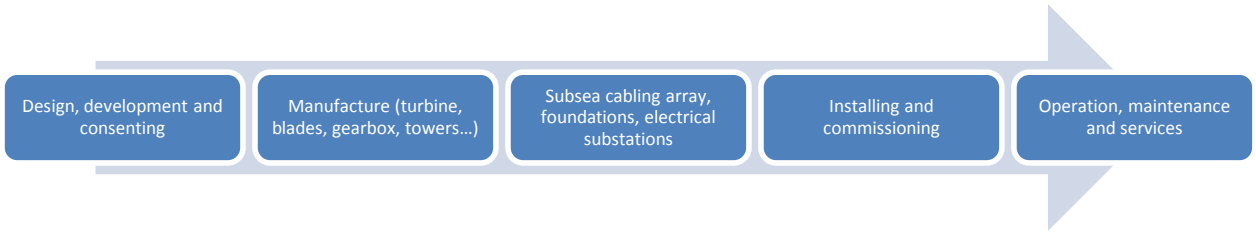


Source: Adapted from PetroStrategies Inc. (http://www.petrostrategies.org/Learning_Center/oil_and_gas_value_chains.htm)

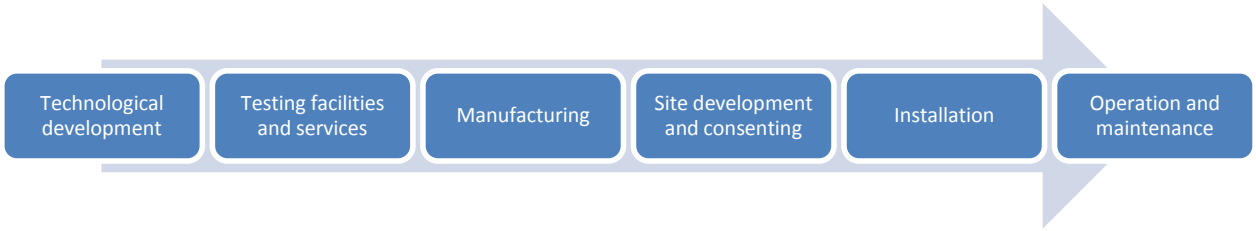
The value chains of other forms of energy production are rather different and for newer types of energy source UK-based supply chains are not fully in place (BIS, 2011 and Figure 2.6).

Figure 2.6: Non-Fossil Fuel Supply Chains

1) Offshore wind energy:



2) Marine energy:



3) Nuclear power

* Site management, nuclear fuel supply, technical services, waste management/disposal

Source: Adapted from BIS (2011)

While technologies for generating electricity from wind are well understood, the innovation challenge for industry is to reduce escalating costs of production for *offshore wind farms*, arising inter alia from supply chain bottlenecks – up to 80% of the components for offshore wind farms constructed in the UK in the last five years are imported from elsewhere in Europe (UKERC, 2010). *Marine energy* (wave and tidal power) is still at the pre-commercial stage. Although the UK is regarded as a global leader in its technological development, access to development finance for costly bespoke manufacturing and deployment is the dominant issue for firms moving into full-scale pre-commercial arrays (TRL 8-9) and the supply chain remains to be constructed in any meaningful way (BIS, 2011).

Instead, the relative lack of R&D activity around *nuclear power* in the last 20 years places the UK at a disadvantage to the leading nuclear engineering nations of the US, France and Japan. With only a few (often elderly) experts covering many areas of research, this raises concerns over the depth of knowledge within the sector, and the universities that have continued to provide a good research and training base in nuclear science and engineering are not producing enough graduates to meet the sector's needs (House of Lords Select Committee, 2011). UK involvement in international nuclear research collaborations is weak, yet participation is important to (re)gain credibility for the UK industry (ibid.). In addition, the 2011 BIS report (p.10) points to the impact of poor incentivisation on the UK's capacity to commercialise its research, despite the excellence of the UK knowledge base.

2.4 Construction

The construction industry in the UK has a workforce of around 2.1 million people, of whom the vast majority are self-employed or work in businesses with fewer than 5 employees. Of the UK's 256,441 construction businesses, only 62 firms employ more than 1,200 people while a further 205 firms employ 300-1,199 staff. The value of UK construction sector output in 2011 was approximately £122 billion, split between commercial, industrial and social (£55 billion, of which £19 billion is public sector), residential (£44 billion, of which £12 billion is public sector) and infrastructure (new plus repair and maintenance; public sector work is £5 billion of the £15 billion value of new infrastructure). Construction accounts for 7% of national gross value added, excluding the contribution of associated professional services such as architectural practices and engineering consultancies.[ix] Deteriorating market conditions due to the recession cut average profit margins from 7.7% to 5.0% in 2010 as workloads fell (Constructing Excellence, 2011).

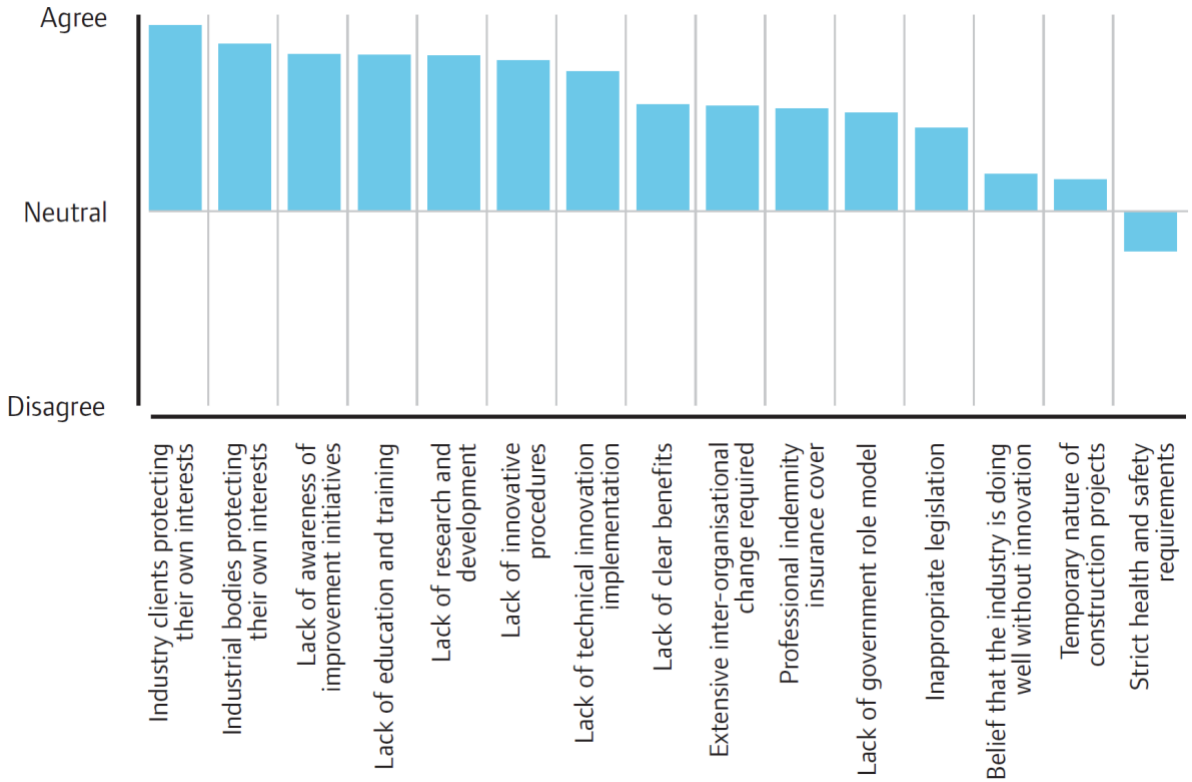
Many components of the construction sector's value chain work on the basis of lowest price, operate under conditions of frequent conflict, suffer from low, unpredictable profitability, and invest relatively little in training or innovation. Firms are organised around a project management business model in which multiple tiers of suppliers provide specialist skills and products to the prime contractor, who is responsible for final delivery to the client. Performance and competitiveness is dependent on the efficient functioning of the entire project network rather than on a single firm (Gann & Salter, 2000), which often makes system-integration a key aspect of innovation in the sector. In the UK, more than in continental European countries such as France and Germany, there is little vertical integration within firms. Extensive use of sub-contracting not only affects the composition of the workforce but also training and attitudes to innovation. It also contributes to infrastructure projects in the UK typically costing 30% more to deliver than in other countries (HM Treasury, 2010). Other factors inflating costs range from lack of clarity at the planning and design stage, over-specification and the application of unnecessary standards,

ineffective competition processes, and tactical rather than strategic investments by companies in the supply chain (HM Treasury, 2010).

'Innovation' within the construction industry is generally not associated with R&D activity. Patenting activity by construction firms is relatively infrequent, yet significant innovation by product suppliers and manufacturers leads to substitute products that offer benefits such as lower cost, greater durability or lower carbon emissions. Official statistics ignore advances in organisational processes, which are crucial given the core role in this industry of contracting arrangements and assembly methods (Manseau & Seadon, 2001). Mass-production techniques such as modularisation and pre-fabrication are slowly being adopted, leading to reductions in production faults and time lost to bad weather.

A study by NESTA (2009) suggests that innovation is driven by market requirements, and possibly by legislative change, rather than by new technology. Moreover, innovation is strongly concentrated among larger firms. The study found extremely low levels of learning from other sectors about the organisation and conduct of innovation. Although the study revealed good examples of innovation practice, diffusion rates were hindered by the limited openness of the sector as a whole. Figure 2.7 indicates the factors found by an earlier study to inhibit the adoption of new practices.

Figure 2.7: Factors Inhibiting the Widespread Adoption of New Construction Practices



Source: Barrett and Lee (2004), reported in NESTA (2007)

Ingrained internal working practices, long-established ways of collaborating with external partners and entrenched divisions between disciplines impede the introduction of innovative techniques. Multiple inter-dependencies along the construction supply chain prevent any single organisation from acting as the authoritative driving force for implementation of a novel solution across a major project (Harty, 2005). Whereas on-site innovation and learning does occur at individual project-team level due to the inherent problem-solving nature of construction work, most of this knowledge remains tacit. The degree of customisation associated with each construction project – related to site specifics as well as client preferences – limits economies of scale from innovation. Low margins are also cited as a reason for the industry's poor record on innovation, because they discourage firms from making significant investments in new technologies; this in turn prevents firms from using technology as a differentiating factor and condemns them to continue to compete for work purely based on price.

Efforts to improve the innovation performance of the industry centre on the development and diffusion of new working practices and the introduction of innovative materials and processes (NESTA 2007). Knowledge Transfer Partnerships between industry and universities with major construction research centres (e.g. Reading, Salford, Loughborough and Imperial College) have led to innovative products and processes, but in general the level of contact between the industry and the UK public research base is low.[x]

2.5 Synthesis

When we reflect on the overall picture of innovation in the four different sectors, while the pharmaceutical model of R&D is relatively well understood (notwithstanding implications of the shift away from blockbuster drugs and towards the greater personalisation of medicine), the more complex innovation architectures of the other sectors are harder to grasp. Neither construction firms nor the energy industry are, on aggregate, big spenders on in-house R&D, yet they are major purchasers of innovative solutions from other actors (Hughes & Mina, 2012), while the CDIT space is mostly occupied by a large number of highly networked small businesses, which are often dependent on technological platforms produced by few and typically large upstream suppliers. The concept of 'innovation' and the construction of value propositions in sectors such as these take on broader and more fluid meanings than may be understood from a singular focus on the UK's highest-spending research-driven firms.[xi]

Disparities in the gestation period for the commercialisation of new ideas help to explain differences between (and sometimes within) sectors in terms of the nature of innovation. Technologies to exploit wind power took up to twenty years to reach maturity, and the various forms of marine power have not yet reached the commercialisation stage after decades of investment in research, but as-yet unrealised supply chain innovation will be crucial to the industry's ability to retain future manufacturing benefits in the UK. This long term science-based effort is more akin to pharmaceutical R&D than to the near-market (and

often service-based) business model of the creative industries – despite the latter's heavy reliance on advances over many years at the hard science-based (silicon, optical…) IT end of the CDIT spectrum.

By contrast, in the construction industry innovation is typically project-based and encompasses technological adaptation and incremental change for site-specific purposes, as well as efficiency-oriented process change and organisational change. Such a conception of innovation emerges as firms seek cost and efficiency savings while simultaneously attempting to satisfy customers in the supply chain hierarchy and (end-user) clients. Innovation is often limited to the demand of a very few forward-thinking clients and is otherwise rewarded rather poorly in the face of slim profit margins. At the same time some elements of the value chain – the highly innovative and internationalised professional service businesses at the upstream end of the sector – make substantial investments in R&D in order to stay ahead of the game.

Differences between industries and sectors in the nature of their innovation endeavours evidently affect the degree to which businesses seek external knowledge and turn to universities for collaborative work, as well as the location within universities of the specific kind of knowledge they seek, and over how long a period they need or wish to work together.

3. R&D Location

The choice of where to locate R&D investments is a key decision for innovative firms and also an important decision from the perspective of the macro context in which it is taken.[xii] The choice of R&D location is co-determined by firm-specific strategic objectives and by the characteristics of potential sites; in turn, it can have a significant impact on growth prospects of host regions. In the short term, R&D location decisions have direct implications for employment growth, while in the long term they can influence future growth through the localised accumulation of technological capabilities.[xiii] Clearly, structurally different firms cannot exert the same degree of control over choices of R&D location. Firstly, these may be significantly constrained by the history of the company and its prior choices. Secondly, only the larger firms will have sufficient resources to maintain multiple sites and to move R&D freely across sites and/or across research areas.

If we consider that the distribution of R&D investments by firm size is highly skewed, it is apparent that the decisions taken by the largest firms will account for the largest share of the changes in the overall private expenditure on R&D of a national economy. Moreover, amongst comparable economies the UK is the most open to international R&D investments and therefore very sensitive to changes in its sources of comparative advantage as an R&D location relative to its competitors.[xiv] It is essential to ask what has been driving the locational choices of firms with an R&D presence in the UK at a time when a number of sectors are consolidating R&D investments and looking to adjust the geographical spread of these investments in light of the growth of emergent economies and of their knowledge infrastructures.

The first clear message that emerges from our evidence is that for firms that can make choices about location, R&D has become a global game. As stated by executives from two of the largest firms in our sample:

> *[1] Globalisation of science and R&D is one of the challenges that any country is going to face now. I can go anywhere in the world to get the right science, I have no allegiance to any country, to any university, to anybody. So we collaborate in China, Russia, Japan, United Kingdom, Europe, America, Canada, wherever the best science is.*
>
> *[2] We think global from the start, we don't think nationally.*

Overall, firms are very clear on the drivers of R&D locational choices, with science-based businesses especially emphasising the role of talent and the quality of science. Interviewees from large pharmaceutical companies observe:

> *[3] It's about presence, it's about connectivity, it's about talent, it's about access. We have sites where the science base is absolutely vibrant and we have confidence that that science base is going to remain vibrant.*
>
> *[4] We have limited funds. We have a limited pot of money. What our researchers have to do is work out who, how and where they want to work with people. It needs to be based on what is driving the science, the projects and their interests.*

[5] I have to follow the skills. If there are options, of course having an existing relationship and geographical co-location are fantastically helpful. But if what I need is very bespoke, then actually I will go wherever that group is.

The identification of access to talent as a major driver, however, is not limited to science-based businesses but includes many firms in our sample whose research and development depends on the recruitment of top engineering graduates and, in the case of pharmaceutical companies, access to patients. But the set of co-determinants of location decisions encompasses a broader range of historical and strategic rationales, including access to entrepreneurial resources (people and external finance):

[6] Part of the decision depends on where we happen to have particular areas of science focus. We happen to have certain research areas based in the UK, so if I am going to increase investment in those areas because I think they are doing well, it will be a UK decision. Others are based in the US and elsewhere. The last new investment we made was in [the US] because there were the academics, there were the entrepreneurs, there is a very mobile work force of highly trained people who work in industry and academia, and we also thought there was potential for co-funding. (Pharmaceuticals Executive)

Proximity to markets is especially important for the later stages of R&D processes, for less R&D intensive investments and for service businesses:

[7] Geographic proximity has a role to play particularly in product development. It's much easier to localise the development closer to the market you are serving, and then encourage the evolution of that invention or enterprise around the world. [As locations for these activities] we chose capital cities deliberately so that we could make a good start with the talent pool that was available in each of them. (CDIT Executive)

[8] Our research activities are located in the UK. Our development activities are located close to our customers. Proximity makes a big difference and we are starting to look at how we can increase our resources in parts of the world. In addition the organisation scouts for new technologies in different parts of the world so we've got people on the west coast of the US but we also look in Israel and the Far East and so on. That's just looking for promising small companies with new interesting ideas and looking for start-up opportunities. (CDIT Executive)

[9] It is a global business so it is about the quality of delivery. We manufacture in various places and we ship all over the world. Customers do not really care, as long as things turn up on time and they work properly. Location doesn't matter so much in terms of research, but in terms of the service we offer it does. We put our spanners and hammers in the regions, and our intelligence in a central place where we can manage it. (Energy Executive)

Co-locating R&D in the proximity of universities is not always essential [10], but it is seen as increasingly important in R&D intensive businesses [11], and especially in the pharmaceutical sector [12]:

[10] The proximity of universities usually is not a driver, but helps. (CDIT Executive)

[11] We decided to have hubs in each of the big regions to get proximity to businesses and customers, and access to talent in those particular regions. And we

tried to do things that made the most sense in terms of where our business is located, or where the high levels of associated university or external research are. (Energy Executive)

[12] A big trend is the location of basic research units into areas of high academic concentration, the sort of biotech cluster areas. One has got better access to academics, better access to talent, and the ability to potentially tap into small companies for partnerships. It has been very positive. (Pharmaceuticals Executive)

Intensive R&D collaboration derives the greatest returns from geographical proximity [13] in particular by facilitating direct interaction with the science base [14]:

[13] The advantage of being close to the university is the ability for people from both sides just to walk across the road, so from a hands-on collaboration point of view it is very quick and it is very easy. Basically our time-to-solution has been much quicker working in that way, rather than working by correspondence all the time with remote partners. (Energy Executive)

[14] Personal connections are critical. That is where you start: you start with the academics. (Pharmaceuticals Executive)

The relative position of the UK research base in attracting investments is overall very positive [15], despite variations across industries linked to the different long-term performances of UK manufacturing sectors [16]:

[15] The UK compares pretty favourably with competitors. Our units in this country are pretty good. They deliver well, they are not more expensive. They are more expensive than China but they won't be for long. I don't start with a geographical bias as to where I am going to invest. And I do think the basic science infrastructure in this country and the ability to attract high quality trained people is still pretty good. (Pharmaceuticals Executive)

[16] Traditionally in the UK we have had lots of TV manufacturers with research bases in the UK, and in fact production in the UK. Over the past 10 years those have been gradually closing and we have got a space today where there aren't really any manufacturers and certainly no research departments really left in the UK. There has been a move from these big manufacturers back to their roots. This has reduced the flexibility to do things unique for the UK. (CDIT source)

The recent closure of a number of R&D sites, with high-profile cases in the pharmaceutical sector, has raised questions over the sustainability of R&D investments in the UK and the resilience of competitive advantage in the UK research base. The evidence we have gathered does not point to signs of weakening in the quality of the science of the country. In relation to the downscaling of pharmaceutical R&D the shared view is that it is the transformation of the overall business model, and not a fall in the quality of UK science, that drives the consolidation of R&D spending:

[17] The reason why companies have downsized in the UK is to cut costs. Every company does that. It has nothing to do with productivity. Nothing to do with the science base. Nothing to do with quality. It has everything to do with just pure accountancy and economics; it's a consolidation on fewer larger sites, because you get economies of scale. It's easier to run companies that are in fewer locations. This is not unique to the UK.

[18] How does the UK retain prior investments? Is it a problem? It is a problem but I don't know that it's a UK problem. The fact is that large multinational companies are being squeezed on profits and therefore they are rationalising. They will always retrench back to a small number of sites. The location of these sites is determined by a whole range of factors, not least the infrastructure they have got there already. I don't think that says anything about the quality of research in the UK. It is a pragmatic decision.

[19] I don't think the sector is contracting in the UK specifically, it's contracting. Companies have closed sites in North America or in Europe as well. Because we are down to a few companies and there are such big changes going on, it feels like they are all pulling out of the UK specifically. But if you sit in France or in Sweden, or in Canada at the moment you would probably feel the same.

[20] [The closure of the sites] had nothing to do with the UK. It was a global strategic change in the way that we do R&D. The UK still has the strong science base.

Importantly, however, this also implies that, at a time of consolidation of investment, areas of clear excellence might make a difference from a global perspective [21] and that the search for more flexibility in the management of R&D investment risk might place even greater emphasis on the quality of potential investees (including both academic teams and small firms) [22]:

[21] The UK needs to be the best in key areas of science in which we are strong. Being mediocre across the board will not any more drive the kinds of collaborations that will be productive. We will invest in a few select places for the areas where there is a common objective or need.

[22] The industry landscape constantly changes more than the academic landscape. And as big companies outsource more, look at a range of inputs from small companies and from academic groups, I think we are all going to have to work harder at gathering that intelligence that allows us to work out where we can invest in an eco-system. So keeping intelligent antennae out there is important.

There is some consensus among interviewees that the search for investment opportunities, which replace research that would previously have been done in-house, is much broader than it used to be given the rise of emergent economies and their long-term investments in their science and skills bases. Costs drive some of these decisions in many instances and across sectors, jointly with the need to gain knowledge about local factor (above all labour) and output markets. Three executives from the Energy sample observed:

[23] We have R&D in Shanghai and Bangalore. Growing our R&D resources in low-cost countries has been a strategic development of the last five years. In India and China it probably costs between a half and a third of what it costs in the higher-cost countries. Of course there is a lot of development work to do in these countries because they don't have the experience. The idea in the higher-cost countries is to stabilise R&D, not to shrink it. But cost in China is not the primary issue; the primary issue is that is where the market is.

[24] Clearly India has some very good technical people and as we continue to grow in India, we want to be able to hire them. I think it's a big question mark if you're growing in a place and you don't have good linkages into universities, are you going

to be able to hire the talent if you want local expertise? From a broader perspective, are you missing out on some great technical expertise to address local challenges?

[25] We have put money into research institutions in China and a lot of that is about relationship building. We want to understand the implications of key business challenges from the perspective of that market.

Specific government incentives are also frequently mentioned by businesses as relevant drivers of new investments. Depending on the sector under consideration, these include tax incentives and the patent box, and more broadly instruments that countries such as Singapore are using very effectively to become a world-leading R&D location. A number of companies from all sectors also cite signals of long-term commitment by governments to particular technologies as a key determinant for R&D locational choices. We will return to this issue in more detail in Section 7.1.

4. Collaborative R&D

4.1 The search for external knowledge

The ability of firms to search for, absorb and exploit external knowledge, and their capacity to trade internally-generated knowledge, are key features of successful innovators.[xv] Firms can access external knowledge in a variety of ways. These include monitoring the development of external research via secondary codified sources (publications or patents), through market mechanisms (the exchange of intellectual property, the commissioning of research projects or corporate control) or through various forms of collaborative research, whether formal or informal. The externalisation of R&D can reduce technological uncertainty, lower costs, enable the exploitation of complementary assets, facilitate entry into new markets, or help to achieve scale and scope economies in research along or across value chains.[xvi]

The increased popularity of 'open innovation' models resonates quite strongly in our empirical evidence. It is certainly difficult to identify a radical and widespread shift in the innovation strategies of all firms, but several large firms report significant commitments of resources to extra-mural R&D:

> *[26] A large proportion of our work is either formally collaborative or informally collaborative in one way or another.*
>
> *[27] There are some projects which we work on internally exclusively because they are of a sensitive nature and you wouldn't want to share that information. But culturally as an R&D department we have bought into the open innovation model. We have been open innovators since before open innovation was what they called it.*

The externalisation of R&D partly compensates for the consolidation of internal R&D spending, although there are differences in the propensity to outsource R&D not only across companies but even within the same large company:

> *[28] The practice of externalisation varies with the research area and with the specific focus of the collaboration.*

Moreover, there is mixed evidence on the extent to which these investments are complements to, or substitutes for, in-house R&D, as pointed out by interviewees from the CDIT [29] and Energy [30] samples:

> *[29] We use external collaborative programmes where we feel we could benefit from it. Most of what we do is internally funded; we use externally-funded activities to complement those activities.*
>
> *[30] [One company] used to have a technology centre with very experienced knowledgeable people. But the whole test centre laboratory was moved to [a university] and is now supported by a graduate training scheme. When you compare it with the depth of knowledge that was in the corporate lab, it is poles apart. Thirty years ago there was a lot more done inside the businesses but we're expecting the universities to do that for us now.*

An increase in the degree of openness of R&D business models is very clear in the pharmaceutical sector [31] [32]. The search for appropriate contractors and external R&D partners is global and sensitive to relative capabilities and costs [33] [34]:

> *[31] Today 50% of everything we have in clinical development is either partnered with a third party or comes from a third party.*
>
> *[32] We have got a 50/50 split between internal and external R&D. We have got almost completely external-facing projects that work with academics. We have got some that are completely self-sufficient and do very little externally, because we feel it's an area that we have got the capability and we are going to protect it.*
>
> *[33] Externalisation is fast increasing as are subcontracts with suppliers in emerging markets. There is strong international competition among CROs [clinical research organisations] and overseas firms can provide cost advantages.*
>
> *[34] The trend in big pharma is to reduce their commitment to internal research, but they still need a flow of products into their pipeline and they access those from small companies. The challenge is they can go anywhere in the world to access these assets. That's why it's so important that we have a reasonable-sized sustainable biotech sector in the UK, because this is how skills get built and value is created. And from a UK perspective you want to generate that value at home.*

The reasons frequently cited for increased collaboration are the uncertainty of technology, its cost and its complexity. As three senior executives from our sample point out:

> *[35] The big thing that has changed is the number of consortia we are in with our competitors. Even 5-10 years ago we would have never have joined up with [competitors] in the things that we are currently in with them. But we can't possibly fund all the science that we need to access on our own. We used to think we could, but we can't.* (Pharmaceuticals Executive)
>
> *[36] In the past we had outsourced to a lot of different companies and then done more of the work internally, but we decided to form some large strategic partnerships where you could really begin to build a very close relationship with the companies that you were sourcing your work with, rather than outsourcing and just sort of passing it over. In other words, making these extended networks much more closely partnered with industry. It's almost like an extension of your internal organisation; it is not an outsourced group that doesn't interact closely. It's a changing partnership model. It's also taking a very strategic look at an area where companies externally have a core business and can do some of your work more effectively, more cheaply than you can internally, while maintaining quality, because quality is really critical in the work that we do.* (Pharmaceuticals Executive)
>
> *[37] I think that there is a trend towards more collaboration because of the increased complexity of problems that we are trying to solve. You can't solve internet problems on your own because the internet is a complex system with many interfaces and I would say that there is a trend over time to do more collaborative research.* (CDIT Executive)

Collaborative research is also increasingly favoured in areas of technical development which involve standards for large systems, as is the case in CDIT platforms:

[38] We have [company 1] and [company 2] who are fiercely competitive in the market but they come along to see us, and they will sit down and they will discuss quite openly the technology, because they understand the benefits of working together with industry to move these things forwards. They agree as an industry that these are the problems that need solving, and these are some of the technical solutions to solve them. They recognise the value of progress for the whole market rather than just trying to go out there on their own. Obviously they will keep some things secret and they will try and exercise their position in the market, but they share enough to give us the ability to move everybody forward, because this is to everybody's benefit.

As executives from three large firms in two different sectors point out, the choice of R&D collaborators is flexible and depends on contingent 'fit for purpose' decisions [39]. Universities are one possible option, but in many cases they are by no means the only choice available [40] [41]:

[39] I spend my research money wherever I can get the result, at a university or with another industrial partner. It is all driven around what our customers want, and they don't care where the research comes from as long as the end product works. I don't have a target to spend so much with industry and so much with academia. I just have a target to get a payback within five years and get a result.

[40] We work with our customers, we work with universities, we work with government, we work with industry partners as well. If we look at formal collaborative programmes where we typically engage for longer term research, they are two to three years each so you can't expect immediate feedback all the time and benefit all the time. University-based is even longer, but I'm not sure that's true any more because now we work with university partners on short and medium and long term [research]. Industry partnerships are usually much shorter term, but we also have what we regard as key strategic partnerships with major suppliers with which we have a programme of research.

[41] Most companies have to be outwardly focused in the digital world. We are certainly outwardly focused in terms of our customers, and our customers routinely ask us, 'Can you do this? Can you do that?' In some cases we can do it with internal resources, in some cases we need some external resource to help, and the universities are often a valuable source in that area.

4.2 Interaction with the public research base

Universities and public research organisations are playing a more prominent role than they used to in the management and policy domains. The establishment of stronger links with the public research base has not only been pursued by companies as part of their broader search for external knowledge, but has been actively encouraged through government policy. In the UK this includes the set of relatively recent initiatives often referred to as the 'impact agenda' of universities, which aims to foster more societal and commercial engagement in the public research base and the expansion of industry-facing activities.

There are several reasons why firms might want to engage in collaborative work with universities, including the need to better exploit their existing capabilities by solving specific

short-term problems and the objective to explore new avenues for innovation and potential growth over the long term.[xvii] There are also several ways in which this interaction takes place, ranging from informal personal exchanges to formal organisation-wide agreements. These are extensively reviewed in the report by Hughes and Martin (2012) on the impact of the research base so we will not repeat the arguments here. Instead, we build on their report, focusing on the perceived challenges and opportunities that emerge from our sample and providing complementary qualitative insights into how such interactions take place and how they could be improved.

Our fieldwork uncovered varying degrees of engagement, ranging from cases where interaction is broad and pervasive [42] to cases where there is little or no collaboration [43] [44]:

> *[42] The UK research base in general is absolutely first class; it's a real asset to a company like us. We wouldn't exist without it because we directly sprouted from that kind of background. And more than that, the continuing dialogue with people in research needs to nourish what we do, and underpin what we do. There is a good base of people, sometimes an outstanding base of people that we can go and talk to, that know at a world class level what is going on in the areas that we are entering. This is really important.* (Pharmaceuticals Executive)
>
> *[43] We do not do much work with universities because for the type of work we are doing university research tends to be rather a long way out there compared to what we are interested in.* (CDIT Executive)
>
> *[44] There is a general lack of connectivity with university or research organisations. There is this belief that the education system is one thing and business is another.* (Construction Executive)

Unsurprisingly, the larger firms in our sample collaborate more with the research base than do smaller firms. There are also clear differences between sectors, with strong interactions in pharma but also energy, fewer interactions in CDIT, and the least amount in construction. In the pharmaceutical sector academic research is coming to play a more prominent role, even considering that university-industry collaborations have historically been relatively more important than in most sectors of advanced economies. Universities appear to be a key component of the emergent business model for pharmaceutical innovation and for the evolution of the industry in the UK:

> *[45] The UK has historically struggled to translate great academic research into fantastic commercial products for the patients. There has been a disconnect, and this disconnect is in the vibrancy of the biotech community and the ability to fill that gap between academia and pharma. What we are seeing now is that there aren't as many biotechs. What is therefore happening is that academics are trying to push their scope broader, taking more stuff into the clinics themselves and entering more early partnerships. And pharma is looking to partner earlier and looking at other ways of funding that middle space, because the biotech companies aren't there in the same way they were in the past.* (Senior Executive)

The role of universities in our energy sample is less central than in pharmaceuticals, but is still very prominent and appears to also be growing because of the firms' need to access the universities' talent pool and to improve the industry's knowledge base:

> *[46] Our purpose is to build science capability. We have a big programme to form closer links to universities to get good connectivity, good expertise that we don't have in-house.*
>
> *[47] Historically we used universities with a known history of working on the issues we are interested in, but the changing nature of technology has opened the scope of whom we work with more broadly.*
>
> *[48] I don't think anybody in [the company] sees universities as a cheaper form of R&D relative to doing it in-house. We need them for their world class talent.*

In CDIT the picture is much more mixed also given the more heterogeneous composition of this sample and the value chain of the sector:

> *[49] What we are doing is pretty complicated stuff so you need the academics, but you also need to have an interest and a desire to play with the technology.*
>
> *[50] We work with universities because they have a deep domain expertise which can genuinely be applied to industrial problems but the quality is variable.*
>
> *[51] I think the situation has changed. Universities are more industry focused and industry has also woken up to the ideas around open innovation, but more importantly to the kind of complexity that it's trying to deal with and recognises the value of academics. There has been huge progress but I do think that it was started from quite a long way back. I think that for many years previously the connection between industry and academia had been quite broken actually.*

In construction, firms at various stages along the value chain look to universities to supply graduates with relevant skills but have historically been less likely to turn to them to conduct research. The latter aspect is changing as economic pressures have grown and as firms recognise the need to work more efficiently, both at a business organisation level and at the construction and engineering level. Private sector clients with their own objectives to meet, primarily around sustainability and carbon reduction, show an appetite for new technologies. But there is also frustration that UK construction companies are too wrapped up in the short-term profit imperative to focus on planning for the future with the development of new technologies (e.g. 'green' concrete), even if some of the fundamental research is being conducted within universities.

Prime contractors, top tier suppliers and major private-sector clients, however, seem to be shifting their contact with UK universities from ad hoc relationships based around the immediate need for a technological solution to more formalised partnerships with the best universities. Recession has brought recognition that, to deliver long term economic benefits rather than a short term fix, businesses do indeed need to engage with the research base:

> *[52] If you had asked me five years ago, when we were without even trying the best there was, I would have said 'I don't care what [a leading UK university] do, we are doing this and the [client] thinks we're the bee's knees'. And then all of a sudden [the*

client] says 'we want it done for 20% less'. Oh right, OK, actually now what is [the university] doing, what are they doing with traffic management, how do you get technology into cars? I think universities will see more coming out of this difficulty in terms of research, because people are going to want an innovative R&D-stimulated step change in what they are doing. (Construction Executive)

As we have emphasised with regard to the R&D location decisions of firms, the search for the right academic collaborator is global, but the importance of personal interactions, facilitated by geographical proximity, is mentioned quite systematically in all sectors. Nor is it limited to cases where interactions exist as part of the history of companies spun out of universities or closely linked to the development of clusters with a strong academic population. In addition, the external source of knowledge a company might look for can easily be a single individual, as opposed to a whole team or institution, with the right skills set and capacity to interact with business:

[53] Collaborations with universities usually start with personal connections that will lead to a combination of things. Obviously they have to be good enough to do the work but we have to know how to work with them, they have to know how to work with us. The brand is no guarantee of being a good project so you can be really surprised by universities you've never heard of and you find an individual who's outstanding in what you want to do, and you can be surprised in the other direction by places with the big brand where the individual doesn't work so well with industry. There are very clever people who find it very difficult to work with industry. So it is about the individual relationship and just how motivated people are to work with industry which is different from pure research assessment five-star type work. (CDIT Executive)

[54] It works better when we start with research relationships and partnerships than when we are approached by a university trying to sell us something. The big value of externally-funded programmes is that they help develop partnerships with people. There's a huge value in those programmes that bring people together. (CDIT Executive)

[55] We tend to work with individual technologists, so it could be professors, it could be straight researchers. But it will be the best person to work with, not just because they are very good but also because we can do business with them. (Energy Executive)

What is really clear is that engaging with universities requires time and resources, and depends on the presence in the business of key people whose role is specifically to engage with universities. Not many companies have such resources or want to create specific roles for these important 'boundary-spanners':

[56] To make these strategic relationships work you have to devote time and effort to maintaining the relationship. (Energy source)

[57] There are lots of areas of research that people just do not know the answers to. It was crying out for us to say 'Well let's pass this over to the universities and see what they have done and can do', to answer some of these fundamental questions. Unfortunately that didn't really happen. I just don't think the right people have been in the room to make it happen. This is probably for a lack of a representative of the industry to be able to have a direct liaison with the universities. (CDIT source)

Several sources also stress that while financial resources are part of the exchange between industry and the research base, money is not the main determinant of successful collaborations:

> *[58] When I talk about partnership, we are not just handing over money; we are putting intellectual input into the collaboration. We are providing knowledge. We may be paying for the partnership by funding a post doc, or a student, or an academic investigator, but we are intellectually invested in the partnership.* (Pharmaceuticals Executive)

> *[59] In most circumstances when we do a collaborative research project it wouldn't be a financial commitment, it would be a joint commitment of time.* (CDIT Executive)

> *[60] Among the barriers to more collaboration with industry there has been a sense that companies will come in and pay for some work, take ownership of it and go away. In other words you would only collaborate with a company because there was money in it. There has been a failure to realise that some of the best academic/industrial collaborations actually do not involve money at all. They are exchanges of intellect or ideas or materials or tools. They do not have to be financially based. But I think things are changing. On both sides.* (Senior Academic)

5. Crossing institutional boundaries

5.1 Objectives and timeframes

There are clear differences in the ways in which academia and industry operate. One major obstacle to collaboration across institutional boundaries is the fundamental difference in objectives between the two types of organisations, with academic research being focused on publications and businesses on commercial output. The following quote captures a widespread opinion in the sample firms from all sectors:

> *[61] The challenge has always been about how one manages to marry the academic sector's objectives with corporate objectives. Academic research can be an end in itself, whereas for corporate organisations research investment has to lead to a tangible outcome and has to be driven by a business objective. You have to be very careful when you agree to collaborate around a project to make sure that those two things are aligned.* (Senior Executive)

The timeframe for the conduct of research differs significantly:

> *[62] The university system favours complex problems of less industrial relevance. So we look for a mix of projects of different types, some long term because we want access to the brain power that correlates around those projects, some others with a shorter timeframe and more focused on industrial outcomes.* (Pharmaceuticals Executive)

> *[63] The issues with academia tend to be around focus and timeframe. From the perspective of a corporate R&D function like ours, we sit in quite a difficult place. We have got a business that is demanding results every quarter. Even if it is innovation, the guys who sit in this building launch product every year, we deploy new products every week.* (CDIT Executive)

Interviewees from several companies, large (but not R&D-intensive) [64] and small [65], often complain that they do not have the necessary resources to engage with academics, as captured in the following two representative quotes:

> *[64] Although it might be all very clever to write something like a paper, and citing lots of other people, actually all that does is put off the business community who don't have time to read these things. So creating good simple commercial digests of research and applicability is really important. And I've seen very few. In a business like ours, unlike some of the others that have a lot more people who also do fundamental research, we don't have people that have the time or the inclination to pair off at an academic level.*

> *[65] Academics need to engage with the industry on a level that industry is operating at. Businesses are fast, they're furious, and they need instant results. At the same time they do have a long term focus. But they won't read the seventy page report that comes across their desk, they just won't do it, no matter what we do.*

It can be pointed out, however, that while the production of business-friendly output might lie in the domain of the public research base, shortages of people in businesses with 'the time and the inclination' to engage with universities is not under the control of the research base. Instead it has to do with firms' strategies and constraints, or with the specific

economic environment in which firms operate which may prevent the deployment of such 'translational' resources.

Despite well-known difficulties in aligning objectives and timeframes, businesses and universities with experience of collaborations tend to agree that:

> *[66] There needs to be benefit to both parties, and the best collaborations are those where there really is a shared vision for what you are trying to achieve.*

5.2 Incentives and attitudes

In addition to and consistently with these differences in timeframes and objectives, incentives are not always aligned to suit the mutual expectations of universities and businesses. Attitudes to collaborations also vary considerably across organisations. Overall, there are greater expectations that universities collaborate with business:

> *[67] There is increasing recognition of the value of collaboration in itself and of the more applied output. Engineers have always recognised applied outputs. Doctors do. But other disciplines less so. As universities and research have become more expensive, there is a greater expectation of accountability. Academic freedom isn't an excuse for sitting in a university doing what you like, so I think academics and universities are feeling more accountable than they used to.* (Senior Academic)

Yet even businesses that express a degree of dissatisfaction at the difficulty of engaging with the research base note that this may not necessarily be due to a lack of appreciation of the opportunity on the part of the academics; instead there is a broader problem of incentives:

> *[68] The challenge for people working in universities is not that they are unaware of the opportunity. They don't have the structure or the resources to deal with businesses. It is not a lack of willingness. Sometimes it is. Sometimes academics or departments really want to focus just on esoteric research, or their own thing, or actually their relationships are purely with other academics and their peers, and not with the outside world. But when that's not the case, even when you find the will to engage, you find that it's very difficult.* (Senior Academic)

The lack of appropriate incentives is addressed very clearly by some interviewees, from universities [69] [70] and businesses [71], who articulate this point in some detail:

> *[69] There is nothing particularly in the academic structure that recognises interactions with industry appropriately. Academia and the research assessment exercise are interested in publications, but pay lip service to industry interaction. If I think about academic careers, if somebody says 'I have got five papers in [a top journal] and six grants', I understand that. If somebody comes to me and says 'I have worked for the last five years in [a top company] and I have been very good but I can't show you anything I have done', you know exactly who you are going to appoint. And that's what happens repeatedly, despite the fact that the second person, if they were in R&D, would bring a huge amount into understanding mission-based research in academia. The movement of people between industry and academia is quite restrictive at the moment for career reasons.*

[70] External partnerships, particularly with the commercial world, do not mean any lower quality of academic scholarship. Leadership within universities is important. Funding is important. And valuing and rewarding in other ways is important. In other words, when somebody is coming up for a promotion, it is important that there is due value given to commercial partnerships, to consultancies, to industrial income as much as to some of the other forms of academic scholarship.

[71] The movement of people between industry and academia is improving, but in the UK people are not nearly as flexible as they are in the US. Many of the academics I know still have quite a purist approach to science. And I think the system does conspire against you in terms of enabling that free movement. It's so difficult to be in the scientific environment getting grants, writing papers, then taking a period out and then coming back and trying to write grants and start writing papers again. Experience outside of the science isn't really recognised that much in the university system. It's not recognised and it's not valued. It's almost seen as something that you shouldn't really do. There ought to be much more movement.

A key role for a 'culture' of collaboration is identified by many of our sources from all types of background. What is also emphasised is the length of time it might take to find a way of interacting that brings the best out of all the partners involved in the collaboration, as well as the importance of understanding what the external partners want, with what objectives and within what constraints:

[72] It is about developing a culture. I think if you had a central function [for collaborative work with academia], it wouldn't work. Instead you need your R&D engineers thinking that collaboration is a good thing, that it is part of their job to talk to the best departments, and if they spot something that is aligned with the technology vision that we have set out, then it is their responsibility to initiate a project with that department. [Senior Executive]

[73] Sometimes industry fails to understand what they can best get out of universities. Industry comes to impose its model on universities, in just the same way that universities try to impose their model on industry. There needs to be, and there is, a much better way. If industry wanted a piece of applied research, the fastest way to do it is in-house. There is no doubt about that; they can devote the resources to it. Whereas universities do lots of other things. If they just say, instead: 'here is a problem: can you try and come up with some solutions?' it would take time because it is probably difficult, but they will get something they could never get in-house. [Senior Academic]

[74] The problem is on both sides. From our side [industry] we needed to get our house in order and become a much better partner and then we needed to be more selective and proactive about seeking those partnerships. And it really has to be driven by culture. [Senior Executive]

There is also agreement on the vital role of trust, clarity of motives and transparency in managing these interactions, as these Construction [75] and Energy [76] [77] sources indicate:

[75] First of all you need to work out what you think you want, where you think you can find it, and then have time to go and look for it.

[76] The most important thing is the climate of trust and of mutual respect. A focus on the project is tough enough anyway and we don't want to make it more difficult by fighting with each other. That climate of delivery I think is very important.

[77] I think being very clear on what we expect of each other is probably the most important thing.

5.3 Perceived trends (Improvement; rationalisation; formalisation)

Despite the call for more interaction, with the highest concentration of concerned observers in the creative-digital and construction sectors, one of the key messages to emerge from our sample is that it is becoming easier for businesses to co-operate with universities and that businesses are developing a better understanding of what to expect from universities and how best to engage with academics:

[78] Things have changed in recent years, in the last decade, with universities and research. I think an awareness has grown within universities that there is interest in using knowledge that might be available to be developed specifically for industry. (CDIT Executive)

[79] Universities have been more flexible about the vehicles for doing research. Academics are more geared up to work on much shorter term, more directed, more focused projects as well. Just generally more flexible and happy just to try an exploratory project. (CDIT Executive)

[80] There is a very much more receptive environment for industry interactions. (Pharma Executive)

Some observers directly relate these changes to a shift in funding opportunities that is pushing research towards more applied and interdisciplinary outcomes:

[81] Things are changing in academia. Firstly, there is more pressure on funding, to demonstrate outputs beyond academia, although many still feel that we [academics] are primarily judged by our colleagues and not by the general public or governments. But it is changing. Another driver for change is a relative decline in academic funding routes so there is a sense that more commercial routes, social enterprise or business or government or NGOs, have to be other forces to support research. Academics are at last beginning to realise that they need to set their questions in a wider context. We have gone down a very specialised route over the last 20 or 30 years in most academia, in the UK in particular. I think there is much more of a drive towards cross-disciplinary work, answering a larger question rather than a more introverted question. (Senior Academic)

Some observers notice differences between generations of academics:

[82] The attitude of some academics is 'Oh dear, I don't want to do this, it's going to be terribly painful'. Well, it isn't, all you've got to do is think before you write anything down or put it in a poster as a public presentation. If it looks like it has got some IP in it, just write a patent. Otherwise, don't bother. However, the young ones are different. I am very impressed by how savvy they are. I am very encouraged by it actually. (Senior Academic)

Others stress that while things are changing, change is not evenly distributed and that the rate of change of attitudes and incentives in academia is not the same:

> *[83] The pace of this change varies by individuals, by disciplines and by institutions. There are certainly some departments and some universities where I don't think anything has changed for 150 years. There are others that are much more outward looking where they have seen the benefits, they have seen their colleagues working with other disciplines and other organisations. So I think it's hugely varied. I would say, overall, attitudes are changing slightly faster than the incentives.* (Senior Executive)

Signs of change in the approach to collaborative work are perceived by businesses:

> *[84] As budgets constrict across our eco-system, people are realising the only way we are going to be successful is to have symbiotic relationships, where everyone benefits. We have to be a little bit less risk averse. We have to be willing to give and not to have to own everything, and to publish, and to do things that are important for the academics. I do think it is getting better and you see it happening across companies. There's more pre-competitive work. There's more peer collaboration with academia. It is getting easier to set up collaborative agreements.*
>
> *[85] There has been considerable learning in the industry as well. About five, ten years ago, the university would be very happy to say 'I want to get five million dollars a year for the next five years and I am going to just do what I want, and I will tell you about something when it is interesting'. And actually sometimes we did that. But I think what you tend to find is the relationships that work best, the real partnerships, are where our scientists are working with scientists in the university, where we have agreements that make sense for both groups, where we share risks and we share rewards.*

In addition to several comments that highlight marked improvements in the way in which universities and businesses interact, two other trends seem to emerge, although more systematic evidence would be required to generalise these findings. In the context of broader searches for external knowledge, and in relation to the need to focus resources which are perceived to have become scarcer, large businesses appear to be *rationalising* the spread of their external collaborations, making even more important the role of strong signals about relevance and quality.

> *[86] We are trying to rationalise the number of institutions we work with so that we work with only the very best.* (Pharma Executive)
>
> *[87] Over the last few years we have been trying to close that gap between academia and industry and to rationalise the types of relationships so as to focus on very high-value ones.* (CDIT Executive)
>
> *[88] Historically, we hooked up with whoever we liked the look of. You couldn't accuse it of being a focused strategy. Now we have picked about ten universities we want to have a long-term collaboration with, because we believe they are either extremely strong over a broad field or in a very, very specific niche in a particular area that's important to us.* (Energy Executive)

The rationale for stricter selection of appropriate university partners might, however, be multi-dimensional and not limited to excellence in research:

> *[89] We have selected the ones we want to work with already. Firstly, they tend to be closer to where we have large points of employment in the UK, and secondly they are better known for training specialists in our areas of subject matter. Thirdly, we would take people that were more keen on working with us on certain selected project areas that we are interested in. And fourthly, we are increasingly working with the universities that are more internationally facing, ones that might have better students and researchers that may study over here and then go back to another country in which we operate.* (CDIT Executive)

The second trend we identify is that this process of rationalisation seems to be linked to a push towards greater *formalisation* of research partnerships and their contractual terms in all sectors. The reason for formalisation is to minimise the time and effort necessary to set up collaborative agreements and also to deepen the interaction with the research base and the search for further opportunities for collaboration:

> *[90] We are in the process of identifying a group of tier-one universities where we will have solid frameworks in place. We can't spend a year negotiating an IP contract for a product that we want to bring to market in a year.* (Energy Executive)

> *[91] We have strategic partnerships with [selected top universities]. We look for a broad institutional relationship where we do have specific engagements going on at any given time. We'd like to know people, find out what is going on. So we're looking for broader relationships across the institution.* (CDIT Executive)

6. Commercialising academic research

Over approximately the last three decades universities have intensified efforts to commercialise the output of their research and have relied on a broader range of direct and indirect mechanisms for the exploitation of findings (know-how or technologies) of potential market value.[xviii] Changes in the regulatory, funding, and organisational frameworks of universities have facilitated the rise of the 'entrepreneurial university' and the expansion of the so-called 'third mission' of the higher education sector in several countries. In the UK there are growing expectations that universities find direct ways to extract value from their research.

One of the key arguments behind this policy objective is the widespread view that the UK as a system is typically very good at generating valuable inventions but is not as good at exploiting them. This perception is echoed in our sample[xix]:

> *[92] Everyone knows that science in the UK is absolutely exceptional. But a lot of the discoveries from UK academic groups were commercialised into very valuable products by, for example, US firms.*
>
> *[93] The UK has historically struggled to translate great academic research into fantastic commercial products.*
>
> *[94] We often punch above our weight when it comes to academic excellence. And we punch below our weight when it comes to exploitation.*

With specific reference to the difficulty of translating academic research into commercial output, with or without industry partners, the majority of interviewees in our sample commented on the problems of IP, financial barriers, lack of business know-how among academics and attitude towards risks.

6.1 Intellectual property rights

The first set of comments about intellectual property (IP), mainly voiced by business sources, is the lack of a strategic focus in the patenting activities of universities:

> *[95] Universities ought to take a long hard look at how they encourage their academics to become entrepreneurs. You have to take a longer-term perspective here; it's very easy to create very low value very quickly. Universities ought to be thinking not about how to make a million pounds within the next year, but how to make thirty or fifty million pounds in the next three years, or five years. You don't contribute by developing IP or selling IP to the lowest bidder just to raise a small amount of money. When universities patent inventions they should have a business plan in front of them that says: having done that, this is how we intend to create real value from it.*
>
> *[96] If you patent something from the university, it should be a very important business decision. It's no good just patenting it and then thinking, well, what do we do now? You should be saying: 'Is this invention worth patenting, and what is our exploitation strategy going to be?' Because the minute you patent, the clock starts running down where you've got to put in more money to sustain the patent. And if*

you haven't thought through what you're going to do, you end up with patents that run out of time, that are not exemplified well enough, not supported well enough, so the intellectual property is rather weak.

The need to emphasise *quality* over *quantity* of instances of technology transfer is stressed in several interviews. In three separate cases this point is made with explicit reference to the short life expectancy of university spin-offs based on weak IP, while several business sources make specific remarks on the very variable quality of IP support services in universities due to shortages of experienced people and of staff with a background in business.

Although not all the organisations in our sample engage in collaborative research, and those that do are not necessarily active in sectors or activities where they can or want to use formal IP protection mechanisms, negotiating IP was often reported to be a problem. This tends to be related to fundamental disagreements about value and to the lengthy process that negotiations might entail:

[97] The groups within the universities that are charged with managing the IP portfolio and commercialising it often have unrealistic expectations. Then they get into the negotiation phase and they're not very experienced at doing that. They overvalue their IP, or have not managed it well in the first place. (Company source)

[98] I think there are financial issues in the universities, where even those who have tried to embrace practical applications become quite short term in what they do. Tech transfer offices must get a return on X, Y or Z quickly. That is not conducive to interactions with large firms. It may be OK for a quick turnaround exit from a spin-out, but even there I would argue it is not a very sensible thing to do. There is often naivety in terms of what constitutes value and as a consequence over-protection of IP at the wrong stage, which then leads actually to more difficult discussions where universities are being more protective of early IP than industry. (Company source)

[99] One of the problems is over-inflating the value of scientific innovation at an early stage. There is a certain naivety about what it takes to deliver [products], or to generate good quality programmes. If you don't know what you don't know it is quite a dangerous thing. And I think sometimes we undervalue what industry brings as a partner. (University source)

Difficulties at the stage of IP negotiation often lead to deals falling through and leave strongly negative views which might prevent possible future collaboration with universities:

[100] We gave up with one or two other universities. Their expectation of what they could control in terms of IPR was completely unacceptable to us. Having tried to negotiate with one university for 14 months on what was a really interesting project, we gave up. (Energy Executive)

[101] Some universities are strangling innovation. They think they're being business-like at IP but they're actually making it very hard to do any work with them. The net result is that nothing happens, so nobody benefits. (CDIT Executive)

Beside reports of negative experiences, a few companies also report that contrary to expectations they had no particular problem reaching agreement on IP:

[102] You would expect IP to be a problem but it's never been one that's really impossible to resolve. The chances are if there is something genuinely valuable, people will find a way through and also I think there is a growing awareness amongst the academic partners about that. They make their money from the grants; they don't make that much money from IPR in reality.

[103] IP is usually discussed per project. Sometimes the universities prefer to retain the IP, and then license it to us for our use. We don't mind that as a model. Obviously that just means the cost is spread on a different basis. The process is fine. The universities we deal with seem to be fine. The pricing sometimes isn't, because they have no idea of what real price means, but the process is fine.

The qualitative nature of our study and the size of our sample do not give our findings the advantage of statistical significance, but overall businesses with a strong track record of collaborations with the public research base – typically larger firms – seem to have fewer problems compared with more inexperienced and smaller firms. In addition, many sources emphasise that although experience of co-operation with business has a positive influence on the ability of older universities to work with businesses, younger universities are often reported to be more flexible in their dealings with industry, including in IP negotiations.

6.2 Entrepreneurial finance, risk and know-how

As far as the use of IP by academics is concerned, several observers in the pharma, energy and CDIT samples point out that a lack of entrepreneurial finance and the low propensity to take risks are preventing full exploitation of opportunities emerging from the research base. Shortages of finance are cited with some regularity as an important barrier to innovation, also in the light of the current macroeconomic framework.

[104] At the moment the situation is very difficult. The cash that's available in the overall system to support spin-outs is very limited. The number of venture capital groups, particularly in Europe, is contracting. Venture capital groups are either going out of business, or raising much smaller funds, which of course limits the range of things they can do. The climate is very demanding at the moment. (Pharma source)

[105] The availability of seed funding is hugely constrained. Most of the venture funding people we talk to are only interested in coming on board when you need growth capital for deployment. (Energy source)

[106] The reason we haven't got our technology running today is purely down to the availability of finance. In the US, seed equity is available for new technologies like this with similar or higher levels of technology risk. In Europe, and in the UK in particular, it is not. (Energy source)

While in the pharma sector the activities, for example, of the Wellcome Trust partly alleviate the financial constraints of early technological developments, such charitable organisations are unique. There is nothing comparable in other sectors, which instead have to rely on public sector initiatives. But from the perspective of a young firm, these cannot be the end-game. The following source from the creative sector helps to exemplify the problem:

[107] There's a basic fundamental challenge which is how to use public money in a way that doesn't create a dependency culture; and, unfortunately, we haven't got past that yet. I think the right direction to go in is to try and use the public funding element of investment to trigger private investment. And to do that more effectively so that businesses are motivated to continue along the trajectory that is right for them commercially, and so that any participating public investment contributes to that trajectory. Alongside that, there's a need to develop businesses that have a much stronger sense of the value of the IP they're actually creating, and the exploitation of that IP.

While access to finance might be a problem, it is the broader business model of many creative businesses that might need to change:

[108] One of the things that characterises the UK creative industries is agency model businesses where work is done on a work-for-hire basis and production is generally at the mercy of large organisations or companies who dictate terms, and generally those are buy-out terms. Gradually that is changing, but it hasn't changed enough. There is an imbalance in contractual relationships between what you might broadly term the creators and the exploiters. There's very little that's been done to rectify that imbalance.

Uncertainty about the rate and direction of government investment has instead emerged strongly from several sources from our energy sample, to the extent that:

[109] People are now scared to invest, because they don't know what changes in policy the government is going to make.

Sources from all our R&D-intensive sectors also point out that the lack of entrepreneurial finance is not related to a general lack of capital in the UK system. Industry sources point out that:

[110] The number one problem in the biotech sector in the UK is the total lack of appetite from the City of London, their shareholder base, for investing in this type of company or in this sector.

[111] The City is awash with money and is reluctant to put it into long-term high-risk ventures. This is the bottom line. There are few people in the City that understand our business. They do, to be fair, raise their money from pension funds, but the pension funds themselves are reluctant to get involved in ventures that have a comparable amount of risk. A lot of people in the City who manage the funds don't have the training to understand the science because they are from different backgrounds.

[112] The business community doesn't help, because even though you have got the City of London, with deep pockets and a massive amount of capital, the attitude of banking to digital content is terrible. If I want to open a restaurant, they understand that and somehow they think that's less risky than a piece of digital content, which is at least equal risk. Maybe we need a Creative Industries Bank with people who understand what we are doing in charge of that portfolio.

[113] On the whole, the European and certainly the UK investment community is much more conservative than the US. It is much more risk-averse and tends to want to enter at a later stage, and there are very few-and-far-between investors at the early stage. As a result of that, and since the economic crisis of 2008, the VC community has moved further to a later stage, which has left a gap, which in the last

couple of years has begun to be filled by some angels. But angels are disorganised, fragmented, and not systematically accessible. Overall they've left a big gap; a gap, which I don't think public funding in the UK has really been able to respond to particularly well.

But not all agree that the real problem is lack of finance, or at least lack of finance alone. Some experienced industry sources point to demand-side problems and the quality of the ideas in search of funding:

[114] For the really good ideas, I think there is money around – not much money, and that pool of money is contracting for very early stage investing – but the good ideas do tend to get financed.

[115] I mean I'm a bit of an outlier, but I don't subscribe fully to the view that the main problem is lack of funding. Clearly the environment has got a lot tougher. But I should say, looking at the last two or three years, that new companies setting up with very good ideas are seldom suffering because people don't want to invest in them. The question is quality of ideas.

[116] I personally am a great believer that there's always money around if the ideas are good. I think there was a rush to start companies, because it seemed to be the thing to do and I think some of the management hasn't been good enough to put their case properly. And, therefore, they fail and then they've said that it's very difficult to get money.

As far as potential academic entrepreneurs are concerned, the limited supply of high-quality ideas might not depend on the quality of knowledge in the science base. Several observers relate it instead to *low propensity to risk* which prevents academics from engaging in entrepreneurial ventures outside academia:

[117] Why is the biotech community in the UK not as strong, or not as proportionally strong, as our academic science? It's to do with the lack of availability of people who are prepared to leave academia to go to a biotech and actually do it. Or people who are prepared to do it again and again and again, so serial entrepreneurs. We don't have many serial entrepreneurs in the UK and it's a real issue. And we say, why is Boston such a great place to do biotech? Because there are people there who have done it again and again and again. You can find people there who have done eight biotechs, five of which have been successful. That does not exist in the UK. It is true that finance has become more difficult to come by, but the argument that the problem is lack of finance is overly simplistic.

[118] There is money available but people have to get out there and do it. In the US people are more confident and less scared of the unknown. In the UK we are more conservative; we are probably a bit more scared of the unknown; we are a bit more happy with our comfortable existence and less likely to make these big changes.

[119] There is risk aversion in academia where taking a punt and failing is seen as a failure. So somebody would say 'I have done some great research, I would like to set up a company, I am going to give 70% of my time for the next three years working in a company'. The first thing that happens is you have dirtied your hands with something commercial so your colleagues are going to be deeply suspicious on day one. Secondly, when it fails and you might not have published papers in that time, that will be seen as a failure, which of course it is, but it's not a terminal failure.

Lack of business know-how is also mentioned in relation to risk-taking as a barrier that limits the number of entrepreneurial ventures started by academics. The solution to this problem is collaboration with industry and the availability of examples to follow. Interviewees from the bio-pharma sample note:

> *[120] In this area it's very rare we see somebody who understands how they can use a trick that they discovered in biology or physics or chemistry and get the right business model to make it sell. Are they going to have the right design that is accepted? Are they going to position it in the market so it influences the whole eco-system? Is it affordable? And will it be used? You are asking somebody to be a businessman, a marketer, an inventor; you never get all this in one box, it's just not possible. You actually need partners that are nothing like you.*

> *[121] We often meet academic collaborators with entrepreneurial or business ambitions. It can help the successful outcome of a project. It is not something they hide, if they have an aspiration. If we are working with them and they have something they are thinking about, we can really help them in that space. We help them ask the right questions.*

> *[122] Lots of scientists say 'I have got a really good idea that must be worth a lot of money and I am sure somebody will do something with it'. That is not attractive for anyone to invest in. However, if you say 'I am prepared to give up 50% of my time to do it', that starts to look a bit more attractive. And if you add to that a serial entrepreneur who knows how to run these things, that starts to look much more attractive.*

6.3 Unintended consequences?

To what extent should universities engage in commercial endeavour as part of their mission? Despite overall positive views on the prospects for university-industry interactions, a few observers expressed concerns over possible distorting effects of the perceived pressure to demonstrate impact on the type of research universities undertake [123], the potentially lesser value to businesses of students who follow a commercially-oriented university education [124], and the overall loss of clarity of motive [125]:

> *[123] Defining 'impact' can skew research in university departments. In chemical engineering, things that are designated as 'high impact' are not at the core of chemical engineering. Actually, the challenges of plain vanilla refinery and chemical plant technology are a fundamental plank to how we address the world's energy challenge for the next fifty years. 'Impact' seems to have a number of unintended consequences, in my view.* (Energy Executive)

> *[124] I think it's incredibly important that we don't allow that time and that period of education and that kind of work [by universities] to be distorted by this so-called commercial driver. I think it's completely misplaced, it's not the function of people on humanities courses to be commercial, or to be driven by business leads. It's precisely the opposite, and businesses benefit enormously from the output of those courses by students and graduates who have a perspective which is more traditionally what universities were about, and it is not driven. So, if anything, I'd say that I'm not keen to try and distort the agenda, or to try and find new ways in which businesses should*

exploit that, because I think it's wrong. I don't think it makes any sense. (CDIT Executive)

[125] I think it's a massive mistake. What is completely missing is clarity of motive. We need to be clear. We have higher education because we want to have a sophisticated work force. That's what universities are there for. [You want] the sophisticated ability to tackle problems. We produce sophisticated graduates, as we should, and we want them to do sophisticated problem-solving when they go into research. Now some of that might have the potential to make money and some not. But if they are sophisticated solvers of problems, industry will come back because it wants to play with them, not because it wants to pick up their intellectual property from their tech transfer office. (Pharma Executive)

Other observers from large and more research-intensive companies point out that universities that respond too strongly to meeting the needs of business might risk the loss of their distinctive capabilities as free thinkers. By attempting to act more commercially, they could end up as a poor imitation of the very business organisations that approach them for new ideas:

[126] Universities are not very good at extracting value from what they do, and you don't want them to be that good at it, because then they won't be good at what they do do. (Construction Executive)

[127] There is a risk that UK universities will lose their base research if they become too business-oriented. They shouldn't try just to attract funding from industry. There are some areas where they should spend money on basic research, retain an element of freedom. (Energy Executive)

[128] It's good in some ways that there is still this difference, because otherwise they would be trying to mimic what we are doing in-house. Academic researchers have to be more open-minded than we can be in the company, otherwise they might neglect a lot of brilliant ideas at the beginning. (Energy Executive)

Academics react against commercial imperatives too:

[129] You have to measure us on mission, and you have to give me ten to fifteen years, because I do not want to produce a better coating on a peanut. I want to produce a cure for TB. And if you don't have a time horizon of 15-20 years, I can give you the peanut coating. (Senior Academic)

And UK universities themselves can send mixed messages about their desire to engage with industry. There is no clear evidence that certain types of university are more likely to become involved than others:

[130] We often get confused messages from universities, depending on their age/type [Technical colleges, Pre vs. post 92, Russell Group etc…] It's not obvious that all of them want to deal with industry. Some want a very high level of independence, and that's largely driven by funding structures and traditional ways in which HEFCE and the research councils work with them. I think some of the universities need to decide if they want to be outward-facing more fully or not. (Industry source)

7. Challenges and missed opportunities

The final set of findings we discuss focuses on the role of policy and on issues around skills and funding, before we move on to consider the competitive advantages and disadvantages of the UK. The concluding section highlights some of the opportunities – possibly missed opportunities – for 'UK plc' that have emerged from our sample of interviewees.

7.1 Government policy

The government policy agenda is perceived by most interviewees as a strong determinant of companies' willingness to invest in UK-based research. A business-friendly operating environment is seen as necessary to underpin incentives to commercialise intellectual property [131]. In particular the pharmaceutical industry and parts of CDIT are relatively content with the incentives to invest in the UK in the light of recent government policy initiatives [132] [133]:

> *[131] Incentivising other people to invest their money in the translation of that [university research] into small companies and start-ups is the important thing. I think there are plenty of bodies out there that'll fund if the climate's right. And just making sure the climate is right and that corporate tax, or whatever sort of tax, is right for these small companies.* (Bio-pharma source)

> *[132] There is a lot government could do: I think one of the things that still is apparent when you work in the US versus the UK, is getting facilities that really are right for you and the way that landlords work for those sites. And the patent box extension and the R&D tax credit looked like it was going to [disappear] at one point, but [it] stayed, because that's very important. And I think maintaining the funding in medical research, at the level it's at, at least, is incredibly important. And incentives to help translate things out of academia into the early phase companies, any incentive that can help that is useful.* (Bio-pharma source)

> *[133] And suddenly like London buses we get computer science being announced for schools, we get high-speed, super-fast broadband being announced, we get a production tax credit announced in the Budget. The Government has certainly got to be congratulated for finally seeing the value of [this] industry in the UK.* (CDIT source)

But other, more critical voices can be heard, particularly with regard to the need for coherent long-term strategies [134] [135] and a broader framework, including immigration policy issues [136], that is conducive to job creation and economic growth. Risk aversion among public sector officials is also seen as a problem in some areas [137]:

> *[134] What doesn't work for industry is government policy saying 'I'm doing this today' but tomorrow it has changed. That doesn't work; particularly when you're talking about energy technologies developed over twenty years.* (Energy Executive)

> *[135] If the government had longer-term infrastructure plans which we could leverage, that would give us more confidence to invest. That, in turn, would give us more confidence to recruit. In other words, these are long-term infrastructure policy questions which lead towards investment and employment. And if we were to be more picky, we would say to [the sector's UK regulator] 'Do you have a pro-*

investment agenda, or do you have a cheap-as-chips pricing agenda?' If they looked at more long-term investment, it would give more confidence to the players who are here in the UK now. (Construction Executive)

[136] Immigration policy is a problem. It seems crazy that in higher education or further education when students — and 70 per cent of them on these courses are from overseas — come here and say, 'Hey this is a great country, I like being here, I wouldn't mind setting up a business here, employ some people and building some IP', they [Government] say, 'No, you're too skilled, you have to go home'. (CDIT Executive)

[137] In the UK, local government officials have an overwhelming authority to say whether something will happen or not. And there are an awful lot of them just happy to stick with what they know. (Construction Executive)

Firms look to government for strategic thinking around the economic benefits of uniting to support major infrastructure projects and indigenous technologies:

[138] There is a need to think strategically and of course that's what all governments are very bad at doing. No policy, no minister is particularly interested in anything beyond the next election, and with infrastructure that really matters because these decisions we are talking about are decisions of decades, not just three or four years ahead. (Construction Executive)

[139] The line that the Scottish government crossed was to recognise that this technology is a huge industrial opportunity – this is innovation with prodigious economic development potential. The bit that excited the politicians was the jobs and the economic potential. (Energy source)

In some areas of activity where the UK's position was previously well-established, companies are migrating to countries that offer better tax incentive packages and other opportunities [140]. Other countries are also seen to be doing a better job of supporting home-grown technologies [141]:

[140] In development terms the industry has gone backwards, which is a great shame. We used to have several UK independent [firms]. They are now foreign-owned. And because international [firms] are country-agnostic, they go where the skills are high and the costs are low [not in the UK]. [One country] many years ago decided that [this] was going to be a growth industry. So they set about creating an eco-system that was attractive to [our sort of firm] by announcing a tax credit, but at the same time investing in universities to give a skilled workforce available for anybody coming in. There's no point in going to get cheap labour if that labour is no good. It's a simple thing: it is access to finance and tax credits plus a skilled workforce. It is the only thing that matters. (CDIT source)

[141] There has got to be an opportunity for Government to incentivise home-grown technologies. I don't know what the answer is, but I think we should encourage and support home-grown green jobs and home-grown technologies. I don't believe we are seriously supporting those technologies and those advancements in the UK as much as I think other countries are doing. (Energy source)

Our sample firms argued for better engagement with Europe, to avoid excessive regulation that stifles innovation:

[142] [One area for improvement] is to work better with Europe rather than against it. Working better with Europe means that we have the ability to have more consistent approaches across Europe more easily than we have today. At the moment there are risks of double regulations, both regulations from Brussels and from [the UK regulator], and as a result that confusion will just slow us down. (CDIT source)

There is a role for government in providing clear leadership and coordination if complicated long-term concepts such as 'smart cities' are to come to fruition in a meaningful way [143] [144]. Such concepts depend for their development on complex inputs from multiple sectors and disciplines, and require both bold policy making and better implementation by policy makers who understand both the governmental and the industrial perspective [145] [146]:

[143] It's been an issue because no one sector has ownership of that [smart cities concept] at all [from the viewpoint of] a UK research and innovation eco-system. I would say this is where we start to fall over quite dramatically. No one sector can do it alone. It needs ICT and the construction industry to come along; and it does need the energy industry to come along. I just don't think we're going about it the right way because that sort of initiative I think requires governmental leadership. Somebody's got to be able to lead. (CDIT source)

[144] There are some areas where it would be useful to say 'Yes, let's coordinate all of this. Let's coordinate the investments industry is making with the investments TSB is making, and coordinate with the research councils against a national agenda.' This [smart cities] is one of those few areas where you could do that. Or rather you have to do it. It's not happening at the moment. (Energy source)

[145] We need a blend of civil servants that understand government mechanisms and industrial advisors, people on the ground who are actually delivering, so we can have government policies suited to what we need to achieve for the country as a whole. Then you need the guts to implement the policies to make it happen. (Energy source)

[146] I think governments have got to be brave and be sector specific. We are too generalist about the incentive schemes that the government has, it's to boost industry generally. Well, we sort of know which industries we've still got the foundation to be world beaters in. It is the job of leaders to work out what they want the future to look like. (Pharmaceuticals source)

7.2 Skills

Businesses want to recruit well-educated graduates who can bring to the firm insights into the latest thinking in their field. There is praise for the UK university system [147] [148], but also some concern about home-grown talent [149]:

[147] The quality of graduates coming out of top UK universities, the quality of the talent, is second to none. (CDIT source)

[148] High-quality graduates are critical. What has been really important in our success in the UK really is the science base and the people. At the end of the day, it all comes back to people, and the skills they have. (Pharma source)

[149] We recruit graduates from UK institutions but very few people from the UK. How do we get more British kids to do technology? They have all come out of British institutions, but if you look at the nationalities of graduates we've employed during the last few years, it's probably two or three Brits among them. It seems that we just don't seem to get British candidates from that background. [At the same time] it's just very interesting to have a varied background of different people. It's not negative at all. Clearly what we are trying to do is get the brightest people, no matter where they come from. (CDIT source)

In CDIT an insufficient supply of talented young people, or difficulties with graduates and SMEs finding each other, is widely seen as a barrier to UK growth [150] [151]. The problem starts well before young people reach university [152] [153], with not enough children attracted to careers in science, engineering and computing [154]:

[150] Big challenges for us are talent, in terms of just engineering talent and essentially competing for that talent.

[151] Despite a high number of graduates in this domain, when you talk to businesses they say that the biggest thing holding them back isn't lack of clients, it's actually lack of the right people with the right skills. So you've got a large graduate base, you've got a large number of small businesses who are looking for people with graduate skills, and they're not connecting together.

[152] The process of science and engineering education has to improve throughout the school system to feed universities with good students.

[153] We need to teach people better in schools, especially computer sciences and maths, and balance that with teaching art. We need people who are learning arts and sciences together. The [university] faculty system we have is outmoded; separating arts and sciences is a 19th century construct.

[154] We simply could not find enough computer programmers in the UK. What we need are computer programmers, artists, animators, not someone who knew the social relevance of Grand Theft Auto on society. The problem lay in schools in that ICT, that dreadful thing, Information, Communication, Technology, was teaching children how to use applications but not how to make them.

Lack of access to a talented skills base is perceived as a threat to the UK's position in sectors of economic importance, partly because – although the risk of generalisation is high – universities are not perceived to be teaching rigorous technical courses [155], and partly because the pool of professionals with 'craft'-based technical skills has disappeared [156]:

[155] Universities have closed several technical courses and have gone into the directing and the arty side of it, and the technology has now gone to the background. Or it is going elsewhere. There's a lot of outsourcing to emergent economies because companies see there's an up-and-coming workforce. We were very innovative at groundbreaking technologies; and you would go off elsewhere maybe to exploit the technology. But now if we are losing [the capacity] to come up with ground-breaking innovative products through the university system and industry, we will be going backwards on the world stage.

[156] It's now much harder to find people who have got the right experience. There used to be a relatively, I won't say large, but there used to be a cottage industry of

people doing this kind of work in the UK. There used to be a lot more places you could recruit professional people from and that's now rather less. And again from the university perspective, there seem to be fewer graduates coming, at least that we are getting access to, that have the sort of skills that we are looking for.

And at a broader level, the UK's pool of entrepreneurial talent appears to lag behind its potential level:

[157] In comparison with the US the UK does not have the same entrepreneurial start-up culture. That bumble bee that's pollinating the flowers. The eco-system lacks what I would consider to be a vibrant start-up community with aspirations to hit it really big. I am not saying this does not exist; I just don't think they exist on a scale that matches the intellectual and financial capital that this country has. (Industry source)

7.3 Funding constraints

The scale of the typical investment matters. It is recognised to be significantly larger in the US [158], and investors there have a broader, much less conservative vision than in the UK or Europe [159]:

[158] Depending on what you want to do, they will bring whatever it takes. The US are an order of magnitude away. (Bio-pharma source)

[159] The attitude towards companies in the US and Israel is more positive from an investment perspective. They are much more inclined to take a risk, whereas the UK and Europe tend to be much more risk averse and more inclined to be look at close-to-market businesses rather than new young companies that need a lot of time and effort. (Bio-pharma source)

At the firm level, UK businesses are not attuned to the possibilities of government funding in the way that some European firms are:

[160] Our German counterparts criticise us for not chasing government funding. This is an integral part of what they do. Their cycle of research, through academia, with industry and manufacturing, their whole model is about getting money to fund the manufacturing because that builds the machine which funds the country. (Energy source)

This, again, highlights a deficit in the country's industrial policy compared to competitors. The UK is also seen to use European regulation less flexibly than its Continental (or US) counterparts in supporting the funding of UK commercialisation efforts:

[161] We are doing some great science; we want a research project to be sponsored with half a million dollars to potentially create a new product for UK PLC, and make the company successful. This cannot be done. Treasury would say that it was very naughty and it was against EU rules. But all I can tell you is [on the Continent] you can walk into places where they are getting massive subsidies for what they are doing. I cannot see why you can't do it here. It also happens in the US with the SBIR.

[162] Unfortunately there is a lot more money floating about in the US than there is in the UK, although the quality of the science here is as good in many instances, if not better. But then there is a lot of money floating around in Europe but I don't think it is being applied very well and it is not very easy to get at. The UK has an environment which is very supportive of symbiotic relationships that exist. What it needs is some impetus in terms of cash. It has some. The question is: 'Could it have more to really push it further?'

Not everyone is, however, pessimistic about finding funds for the translation of pre-commercial research into new companies [163] as long as the business environment is broadly positive [164]:

[163] *I think for a long time there was a dearth of early stage capital, and that was a big missed opportunity because there was no easy mechanism for taking academic innovation and translating it into product-based companies. That I think is improving, and I think over the next years will improve dramatically.*

[164] *I think having an environment which is positive for entrepreneurs and positive for venture capital investors is crucial. And I stress 'venture' because venture is all about building companies and building value, as opposed to private equity, which is all about maximising value from existing opportunities. VCs are the people that really create new companies, create new employment, create value by taking academic inventions and moving them on to the next step. I think it's a very important component of the whole technology transfer apparatus. We've got to try to encourage that as much as possible.*

7.4 UK competitive advantages and disadvantages

Praise for the research base and its contribution to UK competitive advantage is widespread [165], even though some concern does exist among interviewees from science-based companies about the sustainability of that competitive advantage [166] [167]:

[165] In the UK there is a very good scientific base. People have been trained well across the various scientific and medical disciplines that we need to be good at in industry. There is a talent pool. They have easy access to Europe which is also, I think, very useful. And then I also think that the eco-system here with the universities and the government funding bodies, and the government as well, is actually very conducive to risk-sharing and partnership.

[166] In the space of a few months I gave talks at Yale, Harvard, Cambridge England and Beijing University. In Beijing I met with some of the brightest young scientists you could have imagined. So the UK should be concerned. I feel a little complacency. The quality of the science is good, I'm just not sure it is necessarily the best. People are being told it's the best and I'm not convinced.

[167] There is high willingness and acceptance of challenge in the UK. It's perfectly acceptable to completely challenge an existing dogma, whereas in the emerging scientific nations this is often lacking. Having said that though, there is a sense at the moment that the volume is growing incredibly quickly in the emerging countries, but the quality isn't. Now there is a risk that we could be complacent because it may not

take too much of a jump in quality to suddenly have a big impact, because there is so much volume and so much funding.

The rise of emerging economies is seen by businesses as a threat to the research position of the UK, if not in the immediate short term while quality catches up [168], but this provides scope to expand collaborative activities in those countries [169]. Partly the threat arises from the sheer scale of funding available for scientific research in some of these developing countries, yet a worrying factor is the apparently growing dis-inclination by firms in the UK to undertake truly long-term projects [170] [171]:

[168] In terms of its scientific standing I think the UK is keeping up. It's just keeping up, but it is keeping up. If you look at where our deals are, where our connections are, the UK is incredibly well represented. It punches well above its weight still. But its strengths are shifting and the science of the developing world is getting stronger.

[169] Most organisations have parts of their operations in China and India. The integrated skills sets that we have here in the UK do not exist in China and they are not readily copied, but clearly they are really strengthening their science base. So there are significant opportunities for partnerships.

[170] The level of R&D spending in the UK from industry is going down. Compared to the R&D investment in some sectors in the Far East, for example, there is a real gap building.

[171] The reason for the under-investment in R&D in the UK is a complicated combination of resting on past success and short-termism. As a country we don't have an industrial strategy. I wouldn't say the entrepreneurial spirit is lost because there is still some great innovation in companies, but there is a tendency to step back and look for the somewhat nearer term.

Relative even to the European powerhouse of Germany, however, UK attitudes to innovation and risk are seen to have advantages:

[172] R&D in Germany is stronger on academic learning, strong on attention to detail and quality of attention to detail, but not so good on time or on cost. We have a far more fleet-of-foot team in the UK than in Germany. In Germany they look at things that are done in the UK and think it is sloppy, but sometimes very innovative. I think the UK is sometimes much more innovative than Germany – and that is some of the risk. When I look at the costs of R&D globally the UK actually is relatively cheap among the developed countries. I would say Germany is at least a third more expensive on the labour rate, and the same with the US. I don't see a marked difference in productivity. (Senior Executive)

Universities are coming under pressure to adapt their internal structures and incentive systems to respond to demands from industry for an integrated approach to inter-disciplinary collaboration [173] and a broader understanding of industry's 'big challenges'. This includes a need to develop cross-disciplinary teaching programmes [174]:

[173] But we still have to break the university department silo mentality of problem-solving and functional excellence within a multi-disciplinary environment. It's clear to us that to solve some problems we have to work across boundaries. Some

universities have really woken up to that and have integrated themselves. Those are the universities that we get a very positive reaction to when we say 'This is our problem', because we come with a problem, not with a department in mind. Not all funding bodies, however, get it. (Pharma source)

[174] There's a lag in tracking what industry needs. Very few university courses teach the kind of skills we need and courses are not joined between disciplines. In the UK it is partly because of the way universities are measured. There's a tendency to stick to old disciplines. To be a good computing department it's much better if you do traditional computing. The same goes for a good engineering department and a good maths department and so on. If you want to do well and just be a five-star computing department, you don't waste your time trying to collaborate with sociology or maths or something else. (CDIT source)

7.5 Missed opportunities?

Our CDIT sample of interviewees identified many opportunities for the UK if certain changes to the system could be effected, including investors' attitude to risk [175] [176] and sheer entrepreneurial ambition [177] – which may be influenced by the scale of the domestic market [178]:

[175] There's a lot of research that sits on the shelf for various reasons and I think there's a lack of entrepreneurs who would put up the investment, or investors who would come and take it forward into a real enterprise, or to get it taken up by other manufacturers. It doesn't have to be a start-up company. The exploitation part of it is the bit where it tends to fall down.

[176] There's a lot of money here but how conservative is the money and so how conservative is the ambition? To me it all comes down to ambition and aspirations.

[177] There's an aspirational aspect; the thing that I would look at is at what point successful entrepreneurs cash out. In the UK they'll cash out at fifteen, twenty, twenty-five million dollars or pounds, and in the US you have people for which a billion isn't enough.

[178] The problem for scaling British innovation is the size of our domestic market. Because in the British context there is a big enough domestic market to be enough of a challenge in the early stages, people scale to that size and then comes the realization that there's a lot of work to then think internationally and get into the real mega scale. They think: 'We could just sell ourselves'.

Whereas large firms have the scale and resources to interact with relative ease with the university sector, for small firms the disparity in size compared with the average university raises significant barriers to their contacts with universities and to their understanding of the advantages to be gained from interaction [179]. But there are more, if more informal, contacts than universities are sometimes credited with [180], and they look for better ways in which to engage with SMEs [181]:

[179] One of the difficulties is encouraging SMEs themselves to be more innovative. The idea of university support is a bit alien to a lot of them. (Energy source)

[180] Institutions like universities find it difficult to engage with many small companies. Universities are big and they employ a lot of people, and they have fairly bureaucratic and codified and agreed structures in place. And that makes it easier for them to align, both easier and, to be honest, often commercially more sensible for them, to align with other big companies. But at the same time there are a number of ways in which this [SME contact] can happen, including partnerships, small grants, vouchers and informal contacts. I think the way in which people who work for universities engage with small businesses is underestimated. It often happens by ignoring the formal processes, because they're just too difficult and bureaucratic. And it is just engaging on an informal basis. (CDIT source)

[181] In Scotland the research pooling system promotes greater collaboration between universities – it doesn't make sense for five universities to put in bids to a big European programme when a collective one could stand a much better chance. Academia coming together in a more coherent way allows clearer conversations with public-sector bodies or with industry. Particularly for SMEs it removes complexity from the system, in terms of encouraging them to engage with academia. (Energy source)

Universities can be important resources for SMEs, providing access to expensive equipment that can help to overcome early commercialisation problems:

[182] The model for university manufacturing research centres is to get through the 'valley of death', which is particularly deep because manufacturing research is pretty expensive. You need expensive kit, and when you get to manufacturing readiness levels 6-9, you need the full range of kit. For individual companies to do that on their own is quite prohibitive.

But in general the UK seems to be taking a rather different approach relative to competitors:

[183] Both Germany and France are much more pragmatic in how they manage competition in their own markets, to make sure their nascent industries have the support they need to get established and to grow.

[184] The UK in my view has generally been pretty poor at helping SMEs that are going through big structural changes. It doesn't look after its little companies, in an industrial sense, as well as other European nations or the US do. We should be having jobs here, not producing another smart invention that ends up being commercialised in China or Japan.

Global ambitions for UK industry are important, if sometimes lacking at the business [185] [186], university [187] or political level [188], as several industry sources point out:

[185] This international growth curve is really going to take off for [this technology]. How do we build a UK supply chain for [this technology], and an international export opportunity for the UK? Getting a foothold in the supply chain is all about innovation.

[186] We have the universities and the ability to educate students. The problem is motivating students to work in an industrial or R&D environment in the UK. We have very little in the UK to attract the best people to stay here. That is the problem.

[187] I don't think universities have strong enough alumni programmes. And secondly they haven't really woken up to the globalisation story. When they have foreign students, how do they stay in touch with them so as to help with outreach of their research to the countries those students go back to? I think they could leverage both these opportunities far more fully.

[188] There is good quality research work in this country, and we can produce good quality products if we want. But there needs to be the political will that we want to do that.

8. Conclusion

The public research base is an essential part of the infrastructure for successful knowledge economies. In this report we have explored some of the main challenges and opportunities perceived to characterise knowledge exchanges with the UK research base. We have specifically focused on the innovation value chains of four different sectors to take into account the variety of patterns of R&D, innovation and collaboration found across sectors and organisations. While some of our findings are specific to particular technologies and markets (and bearing in mind that we cannot claim to have covered a fully representative sample of businesses and higher education institutions), several key conclusions have emerged from our empirical investigation.

First of all, R&D location decisions are increasingly global, with the availability of talent and the quality of the research base as clear drivers of location decisions for science-based businesses. Proximity to markets is especially important for the later stages of R&D processes, for less R&D-intensive investments and for services. Location of R&D in the proximity of universities is not essential but is seen as increasingly important in R&D-intensive businesses. While the relative position of the UK research base in terms of attracting investment remains very positive – despite variations across industries linked to the different long-term performance of UK manufacturing sectors – the fast-growing investments in skills made by emerging economies and the considerable incentives for R&D offered by their governments cannot be ignored.

We find increased partnering and externalisation of research, although it is difficult to identify a substantial and widespread shift across all firms and sectors. Moreover, evidence on the extent to which these external investments are complements to or substitutes for in-house R&D is mixed. Across all sectors the principal drivers of increased collaborative activity are uncertainties around technology, its cost and its complexity. Particularly in areas of technical development that involve standards for large systems, firms are increasingly favouring collaborative research. Their choice of R&D collaborators is flexible and typically depends on contingent 'fit for purpose' decisions. Collaborations entail varying degrees of engagement, ranging from cases where interaction is broad and pervasive to those where there is little or no partnering (and indeed none is needed).

The propensity to enter into collaborative arrangements clearly differs by firm size and sector, with strong interactions in pharma but also energy, rather fewer interactions in CDIT, and the lowest level in construction. Collaboration is a time- and resource-intensive activity, the progress or intensity of which is often related to the active role of 'boundary-spanner' employees who oversee knowledge exchanges across organisational domains – of whom there are far too few examples. Contrary to common belief, financial resources represent only part of the exchange between industry and the research base; nor is it money that determines the successful outcome of collaborations: the primary characteristics of fruitful partnership involve time spent together and the exchange of ideas, materials or tools.

It is clearly important to recognise that business and academics operate under different objectives and timeframes. Academic incentives, for instance with regard to promotion, are still centred around publications and grant proposals rather than industry collaborations – a fundamental misalignment with businesses that are purely focused on commercial objectives. The potential for labour mobility between industry and academia is hampered by issues such as poor recognition within the university system of external industrial experience. Our sources identified the importance of nurturing relationships over time and of understanding the institutional culture ('what makes them tick') as well as the constraints (what they would like to do but cannot) that operate within the other party's environment. Managing interactions successfully is vitally dependent on trust, clarity of motives and transparency.

Even though further systematic research is needed to generalise the findings emerging from this study, a key message from our evidence base is that industry-university collaborations are improving, not least because businesses now have a better understanding of how to engage with academics. University attitudes are also changing, albeit not uniformly across departments or institutions. Other emerging trends in university-industry collaboration concern the rationalisation of relationships (with the selection of a smaller number of high-quality interactions) and their formalisation (in the interests of limiting the time and effort required to establish agreements).

With respect to the commercialisation of academic research, our evidence reinforces the view that the UK is generally very good at generating valuable inventions but rather less good at exploiting them. It is, however, important to point out that it is hard to find systematic quantitative evidence of this 'paradox': the extraction of value from research is difficult for all countries and is increasingly problematic given the internationalisation of R&D activities. Overall, the interviewees in our sample identify the critical barriers to commercialisation as: intellectual property rights, finance, lack of business know-how and attitudes to risk. Specifically, from a business point of view universities have often lacked a strategic focus in their patenting activities and underemphasised *quality* relative to *quantity* of instances of technology transfer. Negotiations over IP are typically described as unduly lengthy, not least owing to fundamental disagreements over value. Yet alongside accounts of some negative experiences, many companies (typically the more experienced firms) also report that they have no particular problem finding agreement on IP acquisition.

An important barrier to innovation cited with some regularity is the shortage of finance, attributable at least in part to the current macroeconomic framework. Nevertheless, some observers note that a lack of entrepreneurial finance is not related to a general lack of capital; rather, the poor appetite among UK investors for risk financing is seen to hamper innovative activity. In the creative-digital sector there is a need for better business models, while uncertainty about the rate and direction of government strategy and investment emerges as a problem in the energy sector. Other observers suggest the fundamental

problem is more a limited supply of truly high-quality ideas in the search for funding rather than a lack of financing per se.

On the academic side, barriers to the commercialisation of the science base include the low risk-taking propensity of university researchers (which prevents them from entering into entrepreneurial ventures) and their lack of business know-how – although there are encouraging signs of inter-generational differences in attitude. But some concerns have also been expressed that the perceived pressure on universities to demonstrate the value of their work to the commercial world can have unintended consequences, for example on the patient, long-term accumulation of fundamental knowledge.

With specific reference to the four sectors on which we have focused, a key challenge for pharma companies is the renewal of the industry's research and business model. The sector is increasingly externalising R&D that was previously done in-house. Higher levels of outsourcing and collaboration bring with them more opportunities for independent R&D providers, smaller firms and universities. The complementary challenge is the growth of a dynamic and well-supported biotech community in the UK, with potential for strong contributions from entrepreneurial academic teams. In CDIT, key challenges are the need to improve the skills level of graduates, modernise the business model of the many small and disconnected firms (including new approaches to IP and value-generation), and develop an outward-facing approach to the digital economy. Up-skilling and an increase in the supply of human capital are also called for in the energy sector, combined with the need for a stable policy framework and strong signals from government which would release investments in innovation. In construction, where we register the least amount of collaborative work with the research base, innovation is instead hindered by excess fragmentation of the value chain, risk aversion, and severe limits to the demand for innovation despite a recognised need to upgrade the value chain and intensify the use of innovative solutions.

Our study reveals a number of challenges that point to missed opportunities for UK plc. Willingness to invest in UK-based research is sensitive to the government policy agenda and a business-friendly operating environment. But risk aversion among public sector officials and the perceived weakness of government in formulating coherent long-term strategies – whether around infrastructure, immigration or other complementary conditions for economic growth – challenge the ability of businesses to form and implement long-term investment plans. Furthermore, the UK is seen to be less supportive of home-grown technologies than other countries, as well as less skilled at working closely with Europe to avoid the potentially stifling effects of excessive regulation on innovation. These are all indications of the need for a more deliberate and explicit industrial policy in the UK.

In universities, a 'silo' mentality that discourages inter-disciplinarity and inter-departmental co-ordination, not least because of the discipline-based organisation of the research assessment exercise/framework (RAE/REF), may hinder the academics' ability to address the 'grand challenges' of the future, despite a number of major cross-disciplinary initiatives supported by the Research Councils, the Higher Education Funding Councils and the

Technology Strategy Board. As for the UK skills base, while there is broad praise for the country's university education, equally there is concern over the inadequate supply of talented young people with strong STEM backgrounds and/or state-of-the-art technical training. The UK's entrepreneurial aspirations remain more modest than its stock of intellectual capital would imply. Finally, while the general picture of the interaction with the UK research base is broadly positive, with excellence in science and much fruitful learning in both business and academic communities, the dramatic rise of emerging economies in the innovation game leaves no room for complacency.

NOTES

[i] These complementary aspects of innovation are explored in some detail in the literature on innovation systems (Lundvall, 1992; Nelson, 1993; Carlsson, 1995; Freeman, 1995 and 2002; Edquist, 1997). For a regional focus see DeBresson (1989), Saxenian (1994) and Cooke et al. (1997). Malerba and Orsenigo (1993), Breschi and Malerba (1997) and Malerba (2004) are classic references on sectoral innovation systems. See also Metcalfe et al. (2005) on the problem of system emergence.

[ii] Etzkowitz (2002); Chesbrough (2006); Audretsch and Phillips (2007); Antonelli (2008). For a long-term view of the changing role of universities in society see Martin (2012).

[iii] Pisano (1990), Ahuja (2000) and Nelson (1993), respectively, are key studies that address these issues.

[iv] Hughes and Kitson (2012).

[v] Much of the background literature of relevance to this problem is covered in the CIHE report by Hughes and Martin (2012), therefore we refer the reader to this related source and will not review it again here.

[vi] There is an extensive empirical literature on sectoral patterns of technical change stemming, for example, from Pavitt's well-known taxonomy (1984). On the notion of the innovation value chain from a strategic management perspective, see Hansen and Birkinshaw (2007) and for a discussion of the relationship between innovation and industry architecture see Jacobides, Knudsen and Augier (2006).

[vii] An example of 'slow burn' technology development is the UK government's investment in Inmos, which was set up in 1978 to create a leading global semiconductor business. Although not a commercial success, the Inmos legacy lives on at the original Bristol site (now owned by ST Micro), through the emergence of a thriving silicon design cluster in the UK southwest, and importantly through its long-term influence on the IT industry's understanding of parallel processing (CIHE, 2010).

[viii] See Hughes and Mina (2012) for the breakdown of innovation expenditures by sector of the UK economy based on 2009 Community Innovation Survey data.

[ix] These knowledge-intensive organisations are the most likely segment of the construction industry, broadly-defined, to operate internationally.

[x] For an assessment of the impact of KTPs, see Hughes and Martin (2012).

[xi] As one interviewee from the CDIT sample put it: '*Within traditional scientific and technology, the innovation process is clearer to describe. In the creative industries that clarity disappears completely, and it's much, much less easy to describe what such a process would involve and where it might occur.'*

[xii] Archibugi and Michie (1995); Florida (1997); Narula and Zanfei (2005).

[xiii] See, among others, Granstrand et al. (1992), Cantwell and Piscitello (2002) and Hall (2011) for broader discussions of the internationalisation of R&D activities.

[xiv] Hughes and Mina (2012).

[xv] See, for example, Freeman (1991); Brown and Duguid (1991); Cohen and Levinthal (1990); Ahuja (2000); Kogut (2000); Argote and Ingram (2000); Powell and Grodal (2005).

[xvi] Arora et al. (2001); Chesbrough (2003, 2006); Cassiman and Veugelers (2006).

[xvii] Bercovitz and Feldman (2007); Veugelers and Cassiman (2005); Perkmann and Walsh (2007); Bekkers and Bodas-Freitas (2008); Kitson et al. (2009); Hughes and Kitson (2012).

[xviii] This literature and a review of related impact evaluations are discussed in detail in Hughes and Martin (2012) as part of the same CIHE project.

[xix] We must, however, point out that it is difficult to find systematic quantitative evidence of this 'paradox' and that the process of extracting value from research is problematic for all countries, not only for the UK.

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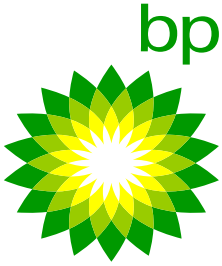

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LEADERSHIP FOR BUSINESS AND HIGHER EDUCATION

The Council for Industry and Higher Education (CIHE) is a strategic leadership network of blue-chip companies working with Vice Chancellors and universities to develop the UK's knowledge-based economy.

The CIHE Task Force on Creative, Digital and Information Technology produced a widely-received and influential report, The Fuse. This resulted in the development of the Brighton Fuse, which brings together researchers, universities and SMEs with the aim of driving innovation and growth within the digital and creative industries around Brighton and Hove. Brighton Fuse is funded by the Arts & Humanities Research Council and involves the Universities of Brighton and Sussex as well as Wired Sussex.

The CIHE Engineering and Manufacturing Task Force recently published Powering Up, which called on the Government to give greater incentives to universities and industry to work closer together. Phase two focuses on the talent 2030 pipeline and will be launched in October 2012.

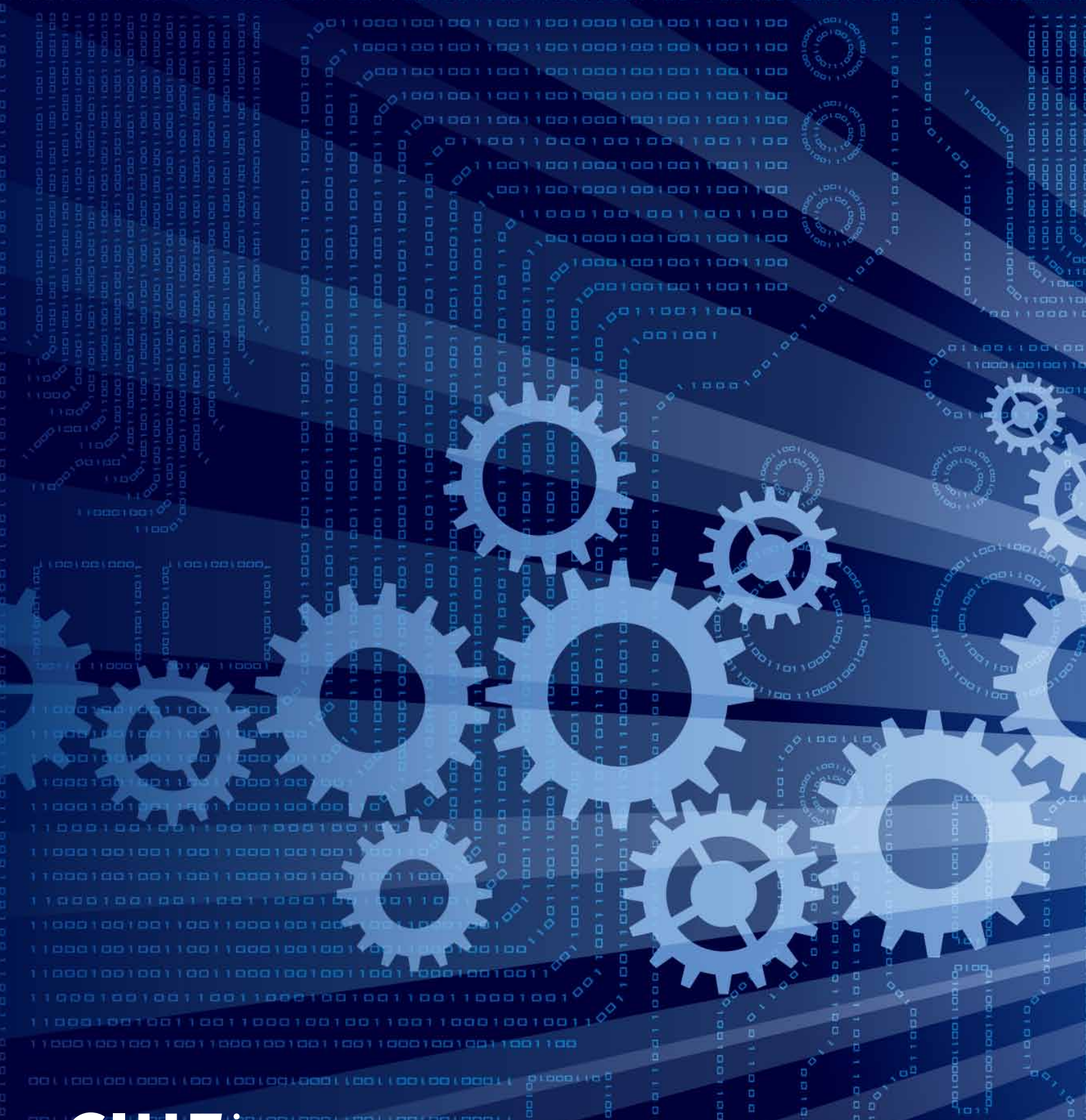
uk-irc

UK-INNOVATION RESEARCH CENTRE

The UK Innovation Research Centre (UK~ IRC) is a joint venture between the Centre for Business Research at the University of Cambridge and Imperial College Business School to further research and knowledge exchange on innovation policy and practice. The UK~IRC is global in scope and involves a large-scale, multi-year research programme and a Knowledge Hub to engage with and inform policy-makers and practitioners about innovation research. The research programme explores open innovation, service innovation, online communities and innovation policy-making. A further stream of research focuses on the nature of university-industry links and role of higher education in innovation systems. Through the Hub, our aim is to maximise the effect of the research on policy and practice, so as to help the UK face its social, environmental and economic challenges.

The Centre is co-funded by Department for Business, Innovation and Skills (BIS), the Economic and Social Research Council (ESRC), the National Endowment for Science, Technology and the Arts (NESTA) and the Technology Strategy Board (TSB). This support is gratefully acknowledged.

- Ensure that new research on innovation in both the public and private sectors has the greatest effect on policy and practice.
- Explore the relationship between innovation and business performance and how this affects the national economy and the individual organisation.
- Actively disseminating its work through a 'Knowledge Exchange Hub', this will include activities ranging from seminars to innovation podcasts.



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