LEADERSHIP FOR BUSINESS AND HIGHER EDUCATION

UK-INNOVATION RESEARCH CENTRE

Growing Value

Business-University Collaboration for the 21st Century

Enhancing Value Task Force

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Foreword

This is the fourth and final report of the Enhancing Value Task Force. At the beginning of the Task Force, we set out to review and research ways of enhancing the value of universities and the public research base, and to make key recommendations to support value creation. In this report, we draw on our three research reports and extensive consultations with business and academic leaders in particular our Steering and Working Groups. We would like to thank everyone involved in what has been a wide ranging and deep engagement with this most vital of challenges for the UK economy.

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"Universities are... first and foremost designed to achieve a new understanding of natural phenomena and technologies: in this task they are naturally inventive. Conversely, in modern free market economies, it is firms that have the incentives and governance structures to make innovation their central goal, and are expected to be the almost exclusive sources of innovation."

Foray and Lissoni, Handbook of the Economics of Innovation[i]

"...the issue is not about isolating the impact of publicly-funded research... It is instead about analysing how best to understand and manage connections...between differently funded and motivated research efforts in a system of knowledge production and innovation"

Hughes and Martin, The Impact of Public Sector R&D[ii]

"It is the job of universities to 'top up the hopper' of ideas."

Ric Parker, Director of Research, Rolls Royce Powering Up[iii]

"Why struggle alone when you can work together? And why not capitalise on the proximity of academia, industry and biotech?"

GSK Case study[1]

1 See p.34 for GSK case study: Biomedical Cluster

Introduction

The quality of intellectual inventiveness in the UK is self-evident. Four of the world's top ten universities are within fifty miles of one another in south-east England, and the UK is second only to the US in academic article citations. And from world class inventiveness in our universities flows world-beating innovation.[2] But **the UK cannot afford to become the world's best contract researcher for other countries' development**. Its inventiveness must be pulled through into innovation within firms to create economic growth and jobs.

Responding to this challenge, the Council for Industry and Higher Education established the Enhancing Value Task Force, led by David Eyton, Head of Technology at BP, and Shirley Pearce, then Vice-Chancellor of Loughborough University. The steering group included David Sainsbury, the UK's former Minister of Science and Innovation, some of Britain's foremost science-based entrepreneurs, R&D directors of global companies, and senior Vice-Chancellors. The Task Force was supported by other CIHE Council Members, such as Sir Richard Lambert, former Director-General of the CBI.[3]

This group set out to:

- Place UK public and private sector research in an EU and global context.
- Explore the similarities and synergies between public and private sector research.
- Isolate the characteristics of different business sectors and explore appropriate sectoral systems of innovation.[4]
- Identify and prioritise a small set of key actions for change that will enhance the value of publicly-funded research and collaboration with business.[5]

Following extensive research on the first three of these tasks[iv],commissioned from the UK Innovation Research Centre at Cambridge University and Imperial College, we have reached ten conclusions and four principal recommendations (see over).

2 The World Economic Forum Report lists the UK as number 2 in university-business collaboration, behind Switzerland and ahead of the US. Global Competitiveness Report 2011-12 Table 12:04.

3 See full list of Steering Group members on p.2. The Steering Group was supported by a working group of highly-experienced business-university collaboration specialists, see p.46.

4 We addressed this objective through 71 interviews with senior business leaders, academics and charitable investors in R&D.

5 We took a conscious decision not to focus on research skills development, which has been extensively covered elsewhere by the CIHE amongst others.

Conclusions

1. There is a global trend towards greater openness in research and collaboration between companies and research institutions. These dynamics are present in the UK, with some institutions being leading practitioners.

2. The openness and excellence of the UK research base is reflected in its attractiveness to overseas firms. The UK has the world's highest percentage of R&D coming from foreign subsidiaries. But this extreme position carries risks. This investment could go elsewhere as developing countries incentivise inward investment, or the UK could increasingly be viewed as providing a higher education and research service 'at cost' to the world. This would profit other countries' innovation systems with little or no follow-on benefit to the UK.

3. Research is a competitive, global activity and developing countries are capturing market share. The UK needs to compete for a greater share of supply chains, from research through to wide-scale deployment of new concepts and products, in order to support the UK's economic prosperity and sustained investment in the higher education and research base.

4. Enhancing the impact of the UK's higher education and research base requires a joined up or systems-based approach, which recognises the linkages from research through to deployment, and from start-up companies through to major multi-nationals, as well as the importance of infrastructure and finance in achieving growth.

5. Large international companies account for the majority of the UK's business research and have the capacity to interface effectively with UK universities and funding organisations. These same companies choose to invest where they can find the best people, leveraging national research expenditures and infrastructure. Smaller companies account for a small fraction of R&D, and those seeking to innovate often struggle to leverage the university and funding systems, due to a lack of resources and relevant 'bridging' skills, both in the companies and in universities.

6. The commercialisation of research is one of many ways in which value is created and it is inherently risky. Large companies are practised at this and have the ability to manage the whole innovation pipeline and portfolio. Failures occur regularly and are to be expected. Smaller companies have fewer resources and a narrower portfolio, making failure terminal, but success also more dramatic.

7. The impact of publicly-funded research is difficult to quantify, but is consistently assessed as strongly positive where capacity exists to absorb the research into business and community activities.

8. Innovation pathways vary by sector, depending for example on the 'clock-speed' of specific industries, industry structure, maturity, and the significance of IP. There is no single 'silver bullet' solution to enhancing the value and impact of university inventiveness that would work across all sectors. Equally, many technologies have multiple applications across many sectors.

9. The absence of an industrial strategy has arguably resulted in offshoring of manufacturing, fewer opportunities for local leverage of the research base and a lack of strategic prioritisation of public research funding. Each sector has a particular set of strategic requirements and particular growth trajectories, and requires specific policy support.

10. Despite having a vibrant financial services industry in the UK, UK inventions often end up being funded by overseas businesses, and their value is not captured in the UK.

Recommendations

1. **Maintain the excellence of the UK Research Base through long-term strategic commitments from government.**

2. **Prioritise and finance collaboration, and the sharing of best practice in innovation, between UK universities and businesses, local and global.**

3. **Promote entrepreneurship and entrepreneurial corporate management in universities in order to enhance risk-taking and innovation in business.**

4. **Develop consistent differentiated sector strategies to incentivise university-business interactions designed to match specific sectoral systems of innovation.**

Recommendations

1. Maintain the excellence of the UK Research Base through long-term strategic commitments from government

The excellence of the UK Higher Education and Research Base is fundamental. It is at risk from changing government priorities and reduced funding in real terms at a time when other countries are investing at an increasing rate. Research funding policy requires a steady hand and sustained long term commitment, not tactical swings in funding by category from one year to the next. Capital expenditure is not a tap which can be turned on and off; it needs to be sustained for the maintenance of the installed base, and flexed upwards when strategic programmes are ready for investment. The £300m government commitment to the Research Partnership Investment Fund, administered by HEFCE, is targeting a further £700m of private and charitable funding and is a good example of the long-term commitment necessary to develop the science and engineering infrastructure.

Once the research base is secure, additional 'in-year' resource allocations should be targeted at intermediating institutions and programmes attracting commercial support, to pull through research to later-stage demonstration (e.g. via the TSB). These should be reinforced by demand-side policies for SMEs, e.g. through R&D procurement. Here the US SBIR is a good model.[v] The keys to the success of the SBIR are the scale of investment in it, its three-stage process across multiple government agencies who invest in R&D, and crucially, its link to public procurement of the technology solutions it supports. Furthermore, SBIR recognises that few small companies have direct routes to markets and emphasise the need for SMEs to have large company partners or sponsors.

If the UK is to be more than the world's best contract research system, government R&D expenditure should favour university partnerships with businesses that demonstrably generate the greatest value in and for the UK. Strong evidence of the intention to create such value would be the existence of UK-based translational research centres. Our research on Enhancing Collaboration concluded that proximity of business and universities is a powerful force for collaboration – witness the many companies, such as Rolls Royce[7], Lloyds Register, Jaguar Land-Rover, and Boeing which have moved or are moving their research scientists or activities onto university campuses. British jobs, products and services are more likely to flow from these R&D collaborations.

However, as part of a long-term strategic commitment to the R&D base, we also need to compete for the brightest minds from around the world, and ensure that there are no bureaucratic impediments to their relocating to the UK. Their decisions on whether to locate in the UK are based as much on perceived government commitment as they are present reality. Recent changes in immigration policies are significantly harming the science and research base.

We support the ambition that the UK should chart a course to investing 2.5% of GDP in R&D by 2014, but note the EU-wide target of 3%. And we also back well-targeted fiscal interventions that respond to global R&D decision making. The Patent Box concept – where corporation tax is reduced on profits from patents – is an example. Many other countries are already giving similar tax breaks. Companies doing R&D in the UK are at a relative disadvantage without such a mechanism.

7 Rolls Royce has one of the oldest university-business collaboration programmes. See p.35 for a case study on its UTC network.

2. Prioritise and finance collaboration, and the sharing of best practice in innovation, between UK universities and businesses, local and global.

There are many good UK examples of collaboration between universities and companies locally, regionally and globally, both in sourcing funds and in conducting R&D. The UK has also been successful at raising university research funding through the EU. However, given the intensity of national competition for scarce UK funds, and the increasingly focussed R&D strategies of leading multinationals, attention needs to shift towards competition for a bigger market share of international funding opportunities, from research through to commercial scale-up. In simple terms, universities in the UK need to work better together, and with companies, to compete successfully for overseas funding for major projects.

We need to build on many of the good collaborative policies and behaviours of the past decade to develop research and fresh initiatives on four key challenges for the innovation system:

- Enhancing connections locally and nationally by building on university-business intermediation, in partnership with funding or collaboration initiatives such as the Technology Strategy Board's Catapult Centres, Knowledge Transfer Networks and Partnerships, and the Knowledge Exchange Programme's Innovation and Knowledge Centres within the Research Councils. These initiatives must be part of a broad-based programme of cultural change within universities in the way that they engage with firms and sectors.

- Promoting symbiotic interactions between universities, big companies, and the innovation-intensive SMEs in their supply chains.

- Using public procurement, in combination with research council funding to universities and TSB investment, to increase cash flow to innovative SMEs emerging from the science base, particularly those in potentially high-growth areas for the economy. This will help ensure investment in disruptive high-technology companies, even when the financial markets are unwilling to accept the risk.

- Developing university IP and investment strategies that focus on long-term holistic knowledge exchange rather than on maximising licensing revenues.

The Council for Industry and Higher Education, working with intermediate organisations such as the TSB and the funding and research councils, should make research into these objectives a priority for the first year of the National Centre for Universities and Businesses which was proposed as part of the Wilson Review of business-university collaboration.[vi] [8]

Businesses must, of course, take responsibility for their own innovation and increase their capacity to understand, absorb and utilise research. There is a role for major companies in working with universities to increase the level of collaborative, innovative behaviour in the supply and value chain. And trade associations and major employer organisations should work with the publicly-funded research base to increase the engagement of innovation-curious SMEs.

8 This work has already begun with the TSB. (See Ternouth, Garner, Wood, and Forbes 2012).

3. Promote entrepreneurship and entrepreneurial corporate management in universities in order to enhance risk-taking and innovation in business.

Most venture capitalists assert that the success or failure of start-up companies is dependent more on the skills of the management team than on the quality of their technical innovation.[vii] There is also a perception that the entrepreneurial culture in the EU is on average more risk averse than in, say, the USA.[viii] Furthermore, major companies require resourceful, inventive talent within their own companies and in their supply and value chains if they are to continue to evolve and grow in the face of global competition.

These challenges need to be addressed, for example by encouraging students to learn from participation in start-ups, and supporting them with formal education and mentoring. Business-facing university departments and schools should take responsibility for engaging students, postgraduates, post-doctoral staff and lecturers in business-inspired problem solving and research activities as the central component of entrepreneurship programmes.

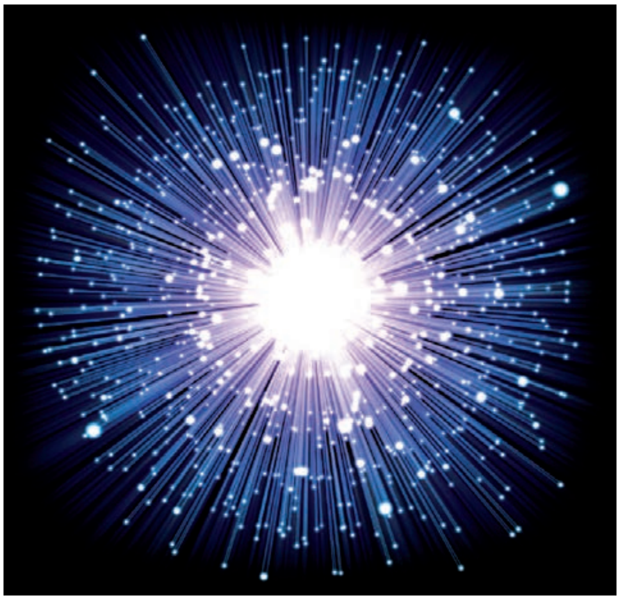
More structured programmes of knowledge exchange between university researchers and PhD students, and R&D departments in business should be developed and promoted to increase the flow of ideas and the understanding of how to commercialise them.

4. Develop consistent differentiated sector strategies to incentivise university-business interactions designed to match specific sectoral systems of innovation.

Clarity and consistency of government messages to business reduce the perceived risk associated with investment. This is particularly true for R&D intensive industries, where the time from invention to wide-scale deployment can be decades. Government departments should be responsible for working with universities and businesses to capture higher global supply chain market shares in the industries they sponsor [the Office of Life Science and the Automotive Council are successful examples of government and business working together to foster innovation eco-systems]. UK Trade and Investment (UKTI), the government department charged with encouraging global businesses to invest in the UK, should work more closely with the British Council and the proposed National Centre for Universities and Business and the HE funding and research councils to coordinate messages and campaigns on the strength and benefits of the UK's research base.

There is also further work to be done by the Government and devolved administrations, working with research and funding councils and business, to develop measures of impact that reflect connectivity and engagement in different sectoral innovation systems. This approach is preferable to relying on simple Return On Investment numbers based on total spend and impossible-to-measure final outputs attributable to that spend.

The trajectory measures developed for the Task Force by the UK~IRC are a contribution to this process. They emphasise the need for different measures at the various stages through which the process of innovation moves, their dependence on complementary investments, and the inherent skewness and uncertainty of innovation outcomes.



These detailed recommendations and the conclusions of the Task Force flow from extensive research and analysis. And it is to these we now turn.

Innovation for the 21st Century

"Whereas a stationary feudal economy would still be a feudal economy, and a stationary socialist economy would still be a socialist economy, stationary capitalism is a contradiction in terms."
Joseph Schumpeter, Capitalism in a Post-War World.[ix]

This investigation has not been conducted in an intellectual or a policy bubble, so we want to touch on some of the underlying economic and strategy drivers that were ever-present in the discussion when the Task Force's Steering and Working groups met.

Managing Innovation

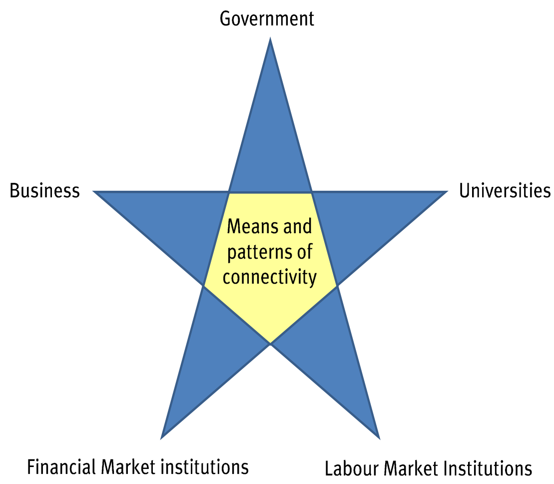
At its simplest, innovation is the means by which economies and firms get successfully from 'here' to 'there'. An innovative capitalist system is never in equilibrium or at rest, and the process by which new ideas are effectively exploited is the inner vitalism of growth. Promoting, stimulating and maintaining innovation is, therefore, a crucial role for all government departments, not just the Treasury or the business department. Whatever the economic ministries do in terms of financial incentives for companies and sectors to innovate, they will in all probability fail if the education system does not produce enough skilled workers, talented scientists, engineers and technologists, as well as risk-taking business leaders and entrepreneurs; if the financial markets are unwilling or unable to share in the risks; or if massive public sector procurers, such as in healthcare, fail to engage systematically with innovator companies and the science base.

There are no easy answers to creating the perfect process or system. Lively arguments over industrial strategy occur because government cannot pull a single lever to see growth appear mechanically (or magically) in a given sector or region. The relationships are organic and historic. They depend deeply on patterns of interconnection within the system.

There is broad consensus among theorists that managing the golden triangle of government, business and universities is central to the successful integration of an innovation system. But this triangular model fails to engage with the financial markets that fund new ideas and technologies, or with the role of intermediating activities and bodies, such as the Small Business Innovation Research Programme in the US, or the Technology Strategy Board in the UK. Furthermore, it does not capture a fundamental point that emerged time and again in our work. We found that the full range of interconnectedness has to be captured to understand economically-successful innovation and the mechanisms that maximise the value of such connectivity.

The shape of an innovation system is more like a Golden Pentangle than a triangle, with the additional points being financial and labour market institutions.[6] Crucially, each of the points must be connected and coordinated in policy terms. (See exhibit 1) As we see later, the pace and ease of connectivity is at the heart of the successful transfer of inventiveness into innovation.

Exhibit 1: The Golden Pentangle



We have sought to capture issues across this innovation pentangle, with a particular focus on understanding, managing and coordinating the connectivity between businesses and universities. We were extremely conscious that the UK's system of innovation is functioning at a time of transformational global changes, particularly in five key areas.

6 Labour market institutions reflect the level and nature of state interventions in the labour market. Examples are, collective bargaining, health and safety, equality legislation, apprenticeships schemes, or pension provision.

Five disruptive innovation challenges

The rise of Open Innovation

Traditional models of closed innovation within firms are giving way to open innovation between companies and publicly-funded research institutions, usually universities. There are many models of such innovation in both theory and practice, but we took the definition of Berkeley academic, Henry Chesbrough[x], creator of the term, as our guide:

> *"Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology. This assumes that partners share risks and rewards."*

As we shall see later, the adoption of this approach to innovation in response to major crises in the business models of the biopharmaceutical industry, or in the emergence of entrepreneurial clusters in the creative and digital industries, has profound implications for the ways in which sectoral innovation policies must be set up to achieve economic impact.

The power of the Internet and high-performance computing

The transformational force of these technologies and platforms lies not just in moving what was once physical – shopping, reading, music, television – to digital, but also in the alteration of physical production itself. Plane wings that were once designed in hangars are now being developed using computer simulation; drugs that were once patiently discovered in labs are being simulated using petaflop processing speeds; and 3D printing will bring customised manufacturing physically closer to the consumer, rather than locating it where wages are lowest. The examples are endless and the implications profound for the management of innovation in the UK.

Global business and global innovation

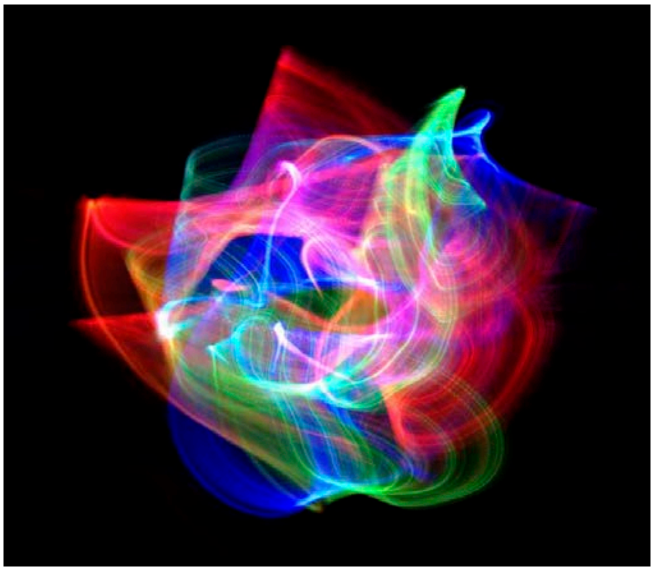
A recurring theme of this report will be the globalised nature of innovation, whether shown in the decision-making of foreign multinationals investing in the UK, in reverse as British companies build R&D capacity abroad, or in the choices of small digital and creative companies to have their web sites designed in Russia and their middleware in India.

The banking and sovereign debt crisis

Innovation is risky, difficult to manage and messy. It requires strong nerves and often deep pockets. In a de-leveraging financial system, where crucial gaps have appeared in venture capital and where private equity is unwilling to fund a high volume of start-ups or sustain high-volumes of innovative SMEs, the role of government in stimulating and coordinating the financing of innovation becomes more significant.

The interconnected challenges of energy, water, food and climate:

These are what Sir John Beddington, the UK's Chief Scientific Advisor called: "The inescapable challenges of the early 21st Century." In this context, our view is that a successful innovation and collaboration system should not to be judged solely – or even mainly – by the number of start-ups or university spin- outs, but by a basket of measures that demonstrate the health of the connectivity within the innovation system, and of course the economic growth that follows.



Innovation and Collaboration in the UK

In September 2012 Vince Cable, the UK's business secretary, outlined a new vision for economic growth which included:

> *"...the courage to take decisions that bear fruit over a long period; openness to new opportunities as they develop; focus on the things we do best; and an enduring commitment far beyond a five year parliament or spending review period."*

Courage, focus, openness to new ideas and enduring commitments are heartland values for any successful innovation system, whether in companies or countries. The mechanisms and context within which these values are embodied are of vital importance to dynamic growth and job creation throughout the economy. As we noted earlier, the most crucial factor in pulling inventiveness into the economy is the design and dynamism of the systemic connections between the main players. But this system is always subject to changes in broader economic and political forces, such as the way in which the UK economy has in the past three decades shifted dramatically away from manufacturing towards services. This has profound implications for the UK's innovation pentangle.

Manufacturing a Crisis?[xi]

The UK has more globally-leading aerospace firms than France, Germany, Italy, Spain and the Netherlands combined, and its skills in high value engineering are evident in the way its manufacturers dominate world motor sports. Pharmaceuticals and life sciences are other research intensive industries where the UK again punches well above its weight.

But start to look more closely at what has happened in the past years, and the picture becomes bleaker. Manufacturing's share of the UK economy has declined more rapidly than in other leading industrialised nations, and at just over 10% of GDP is at an all-time low. Furthermore, a high sterling exchange rate hammered its share of world trade in the decade to 2007. During this period, growth in the UK's manufacturing exports was the slowest in the OECD area.

Big companies have become increasingly concerned about the health of their domestic suppliers as component making has shifted offshore: the British content of JCB's famous backhoe loaders fell from 96 to 36 per cent between 1979 and 2009. Some large firms worry that weaknesses in the supply chain could reach a point where their own businesses will have to move elsewhere.

One striking feature of the past decade has been a rapid increase in foreign ownership of UK manufacturers. By 2007, over 30 per cent of manufacturing employees were working for foreign affiliates, and nearly 25 per cent of business R&D funds were coming from abroad, more than five times the proportion in Germany. Back in the 1980s, many leading building material manufacturers were headquartered in the UK and active all over the world making cement, concrete, roofing tiles, plaster board, aggregates and the like. Today, nearly all of them have been acquired by companies from France, Switzerland, Mexico and elsewhere. Why might that have happened? There are three theories:

- Too much consumption by consumers and not enough investment into UK manufacturing companies via savings. The UK is at the bottom of the league table for investment rates expressed as a share of GDP: 16.8 per cent, compared with 21.9 per cent for France and an extraordinary 41.1 per cent for China. This could mean that long-term investment in plant and infrastructure suffered.
- Too great an emphasis on shareholder value and the short-term. Manufacturers have been especially vulnerable to these extremes, in part because their large book of fixed assets has led to all kinds of corporate manoeuvring in the name of shareholder value. ICI and GEC were for decades two of the UK's most important manufacturing companies. Both were destroyed within the space of a few years by inept financial engineering.
- No clear and consistent sectoral strategy from government. Over the past thirty years, the view has grown that any intervention by government in the workings of the economy is likely to be damaging. This view is only now being challenged, as a consequence of the financial crisis.

The UK's Innovation Pentangle, and the relationship between business and universities, must therefore be managed in the context of the broad shape of the economy, and at the service of industrial strategies for high-growth sectors. To aid our understanding of these issues we commissioned three research projects: the first on the UK's R&D Landscape, particularly in an international context; second, on the impact of public sector research; and finally on collaboration and innovation within key sectors.[9] And it is to those that we now turn.

The UK R&D Landscape

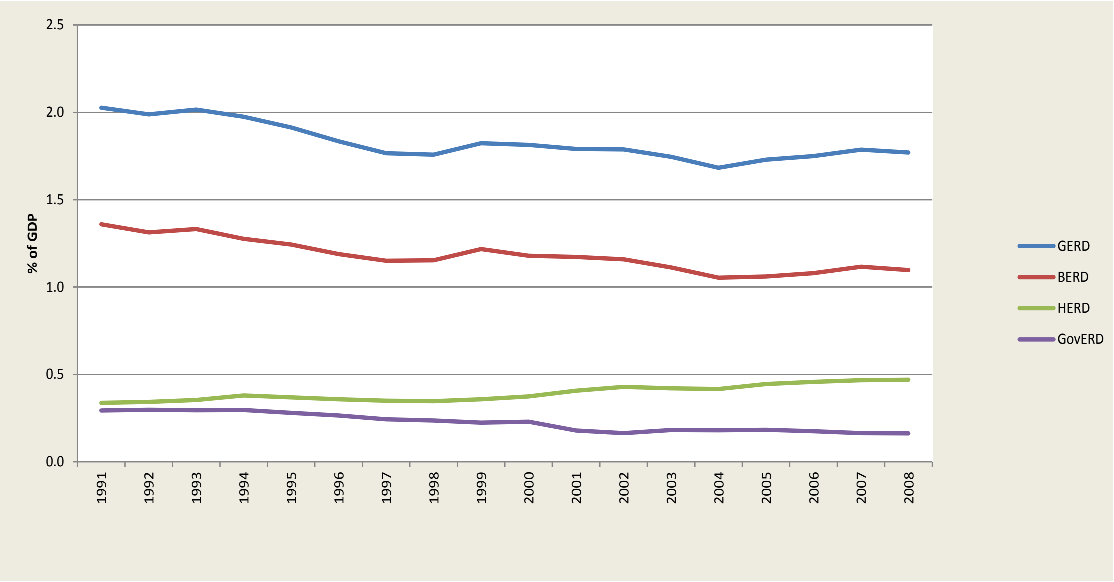
Core messages:

- There is an R&D expenditure gap between the UK and comparable competitor nations.[10]
- R&D is concentrated in the UK's biggest firms and their supply and value chains.
- The UK innovation system is simultaneously open and vulnerable.

a) The Expenditure Gap

Overall, despite an increase in the ratio of higher education research to GDP, there has been a fall of total gross expenditure in R&D relative to GDP since the early 1990s, which has only recently been checked (see Chart 1).

Chart 1: UK R&D Expenditure as a percentage of GDP [11]



Data source: Office for National Statistics

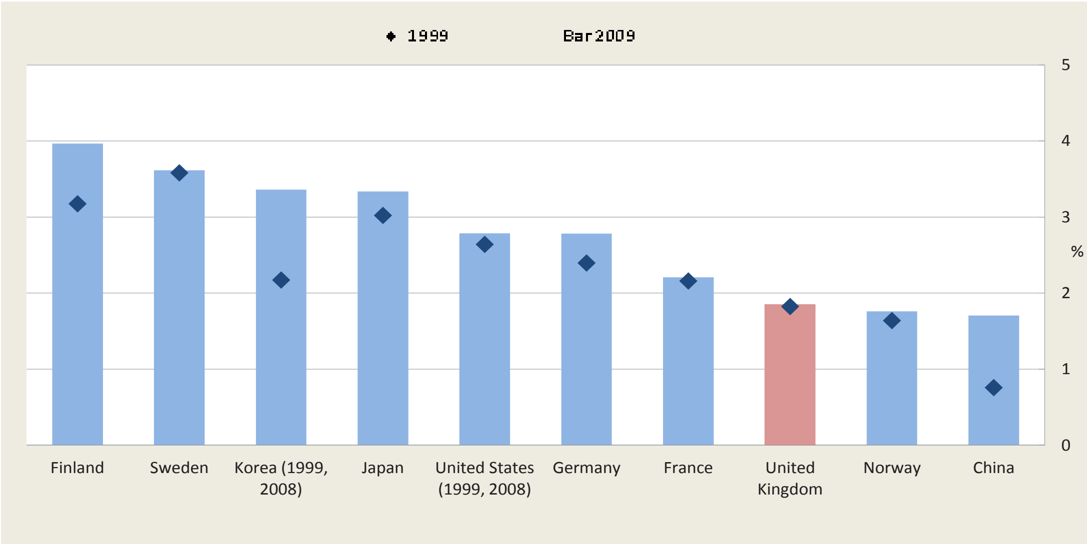
Moreover, in international comparative terms, R&D expenditure relative to GDP seems to be weakening over time, with Korea, China and Finland investing heavily and the UK static (see Chart 2).

9 Although we relied substantially on these research reports, our conclusions and recommendations draw on the debates within and between the working and steering groups, and from the case studies on collaboration.

10 We are conscious that R&D must be analysed alongside intangible investments which include design, copyright development, market research and advertising, software development, training and skills development, and broader organisational change. However, our evidence shows that they were all declining in money terms from the early 2000s onwards. Hughes and Mina (2012 p. 11).

11 GERD:Gross Expenditure on R&D
BERD: Business Expenditure on R&D
HERD: Higher Education Expenditure on R&D
GovERD: Government Expenditure on R&D

Chart 2: GERD: gross domestic expenditure on R&D, 1999 and 2009 (as % of GDP)

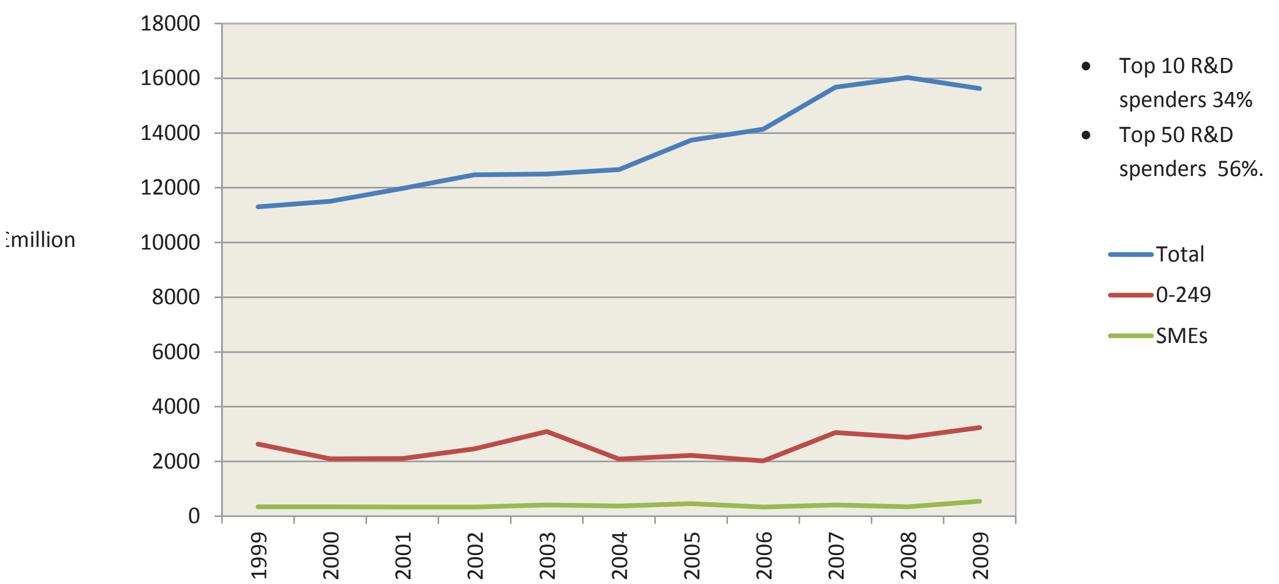


Data source: OECD

b) R&D is concentrated in big companies and their supply chains

The 10 largest business R&D spenders accounted for 34% of all UK R&D in 2009, and the 50 largest for 56%.[xii] Only around 3.5% of the total investment in R&D came from the many thousands of independent small and medium sized businesses employing fewer than 250 people (see Chart 3).

Chart 3: Expenditure on R&D performed in UK businesses by all businesses and by small and medium sized businesses, 1999 to 2009



Source: Hughes 2012 and Hughes and Mina 2012

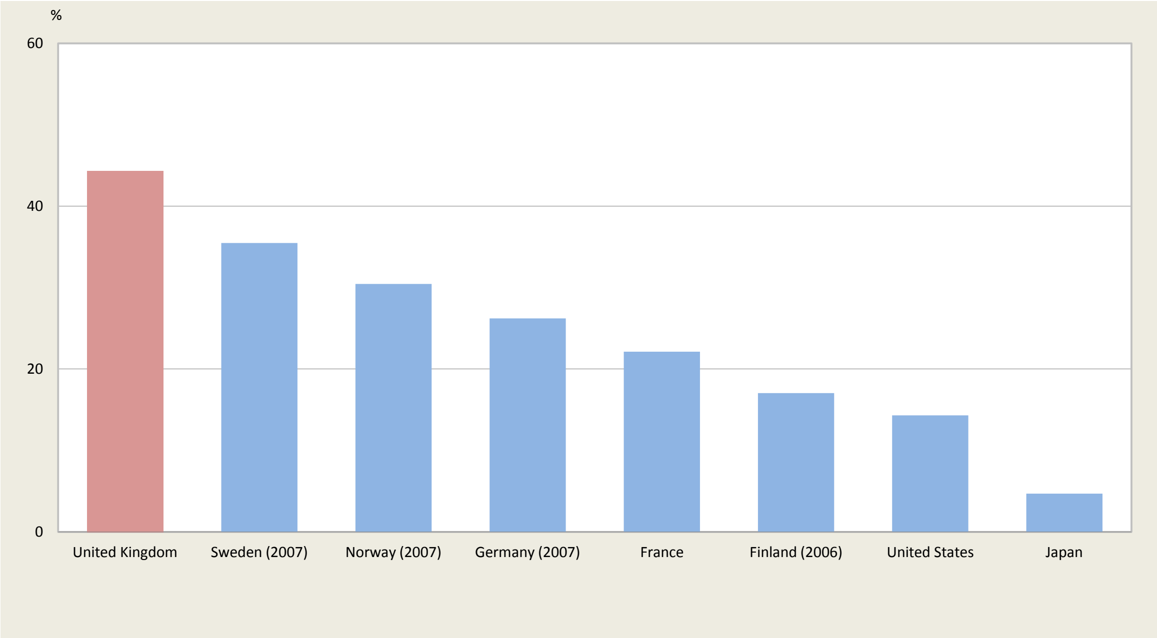
Note: The 0-249 group includes subsidiaries of larger businesses. The SME group is independent firms with less than 250 employees.

The loss of a major research facility from a global business would require literally tens of thousands of new SMEs to compensate for its impact on the volume of UK research. Governments must have policies to support and stimulate innovation in large corporates, SMEs and academia. If one part of this triangle is not supported and fails, then the other parts atrophy.

c) An Open But Vulnerable Innovation System

Over 40% of R&D investment comes from foreign subsidiaries, making the UK the most open – but vulnerable – innovation system in the industrial world (Chart 4).

Chart 4: R&D expenditures generated by foreign-controlled affiliates, 2008 (as a % of BERD)



Data source: OECD

Alongside this inward investment, there has been an outward flow of R&D funding to other countries. In 2009, UK businesses funded £11,519 million of R&D in the UK, but in addition they invested £2,228 million overseas. And this ratio has increased over time: in the year 2000 there was a ten to one ratio between the sums invested in R&D in the UK and abroad, but by 2009 the figure had dropped to five to one.[xiii]

Having reviewed the relative scale and shape of investment into R&D, the research team turned to the impact of that investment, and in particular that of public sector R&D.

The Value of Public Sector R&D

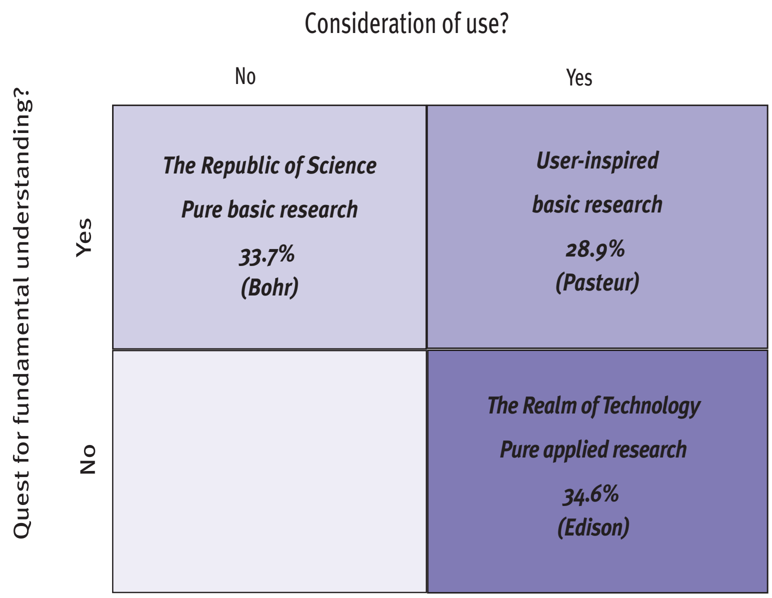
Core Messages:

- UK public sector research investment yields substantial benefit to society in economic and wider social terms; rates of return can range between ten to twenty-five percent over a long time period.
- The impact of public sector research investment depends critically on the private sector investing alongside.
- As with all innovation-related investment, a small number of successes account for the bulk of the return.
- Where it is possible to quantify impact, attempts to reduce it to a single rate of return require heroic assumptions, and it may be a serious policy mistake to rely on rate of return calculations as evidence of the health of the innovation system.
- More sophisticated systems-based methods of impact measurement, emphasising intermediate and trajectory-based measures, must be adopted across the research collaboration and innovation landscape in order to guide policy development.

Holding the innovation system to account by evaluating the impact of the public investment pound is never a simple question of calculating the return on investment. All boards of businesses review a range of metrics before committing to R&D, but none expect every pound, dollar or yuan to be productive. Google famously expects its software engineers to spend 20 per cent of their time on personal projects that may benefit the company, but which may just be an honourable dead end; BP set up an institute in Cambridge to do fundamental work on multi-phase flow with no immediate or even mid-term commercial objective[12]; and many companies engaged in innovation allocate resources between product-led work that will have clear commercial potential, and research that may transform the whole industry – let alone the company – where the successful strike rate is one in ten, twenty or thirty depending on the appetite for risk.

In the same way, public sector research is, and should be, spread across different ways of doing research, and different paths to impact. Donald E Stokes at Princeton challenged the hard and fast distinction between basic and applied science when he developed the Stokes Quadrant – a vivid means of expressing different approaches to R&D named after representative scientists and innovators, and showing the balance between considerations of use versus the quest for fundamental understanding (see Exhibit 2). UK public sector R&D takes place in volume in each of the named quadrants, and the balance shows no significant shifts over time.

Exhibit 2: Stokes Quadrant



Source: Adapted from Stokes (1997) and Dasgupta and David (1994)

Note: Percentages refer to the amount of research council funding accounted for by each category in 2007/8. Experimental R&D accounted for 2.8%

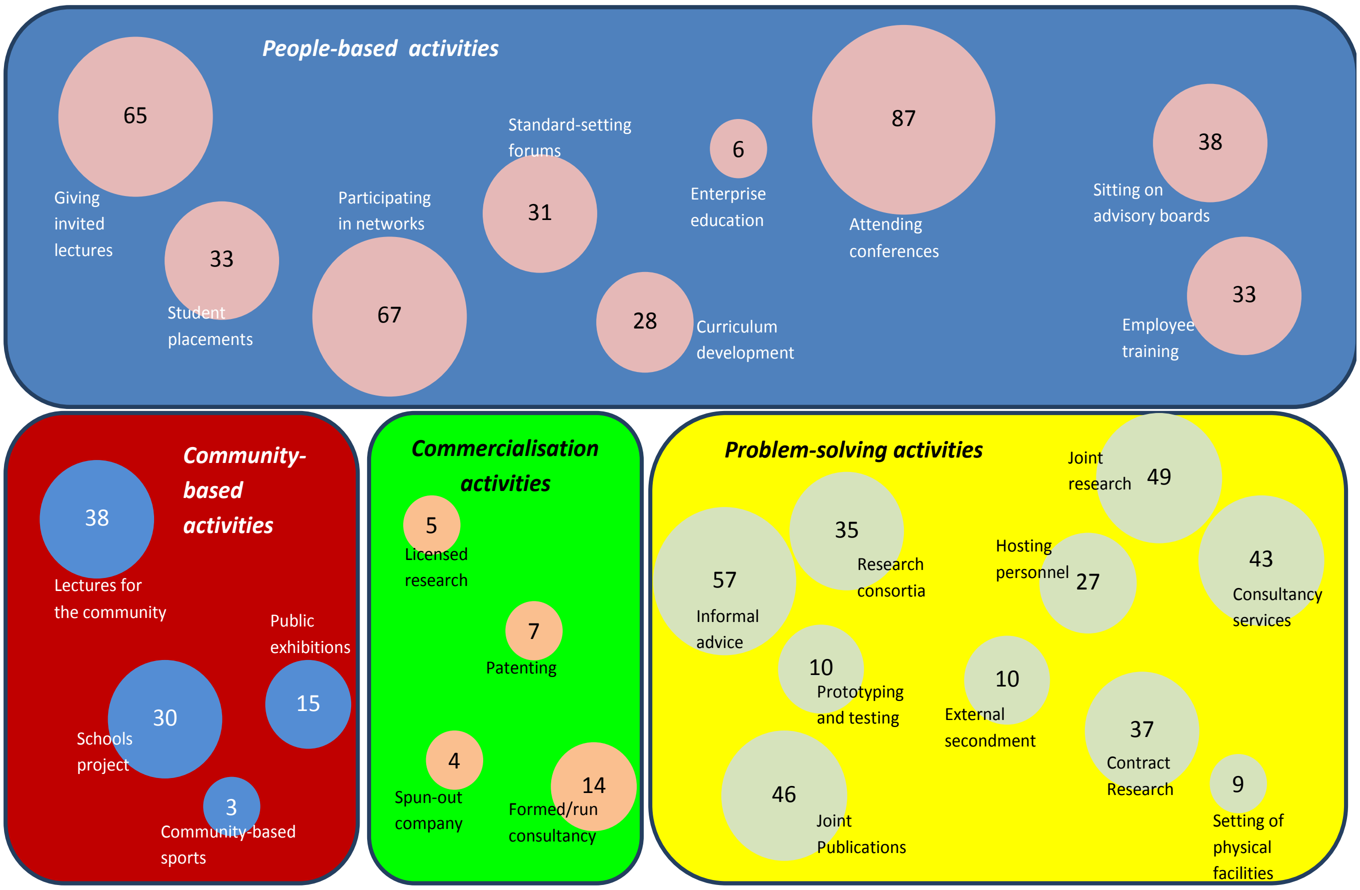
12 See p.38 for a case study on BP Institute for Multiphase Flow.

As the US National Academy of Engineering notes: 'numerous diverse, robust, and often mutually reinforcing vectors link academic research to industry, including direct hiring of students, graduates, and faculty; temporary exchanges of researchers; faculty consultancy; industry-sponsored research contracts and grants; research centres; consortia; industrial liaison programmes; technology licensing; start-up companies; publications; and conferences'.[xiv]

The current rich pattern of impact pathways is shown in Exhibit 3.

Exhibit 3: Impact Pathways of UK Academics

(% of academics reporting each interaction with an external organisation in the last three years)



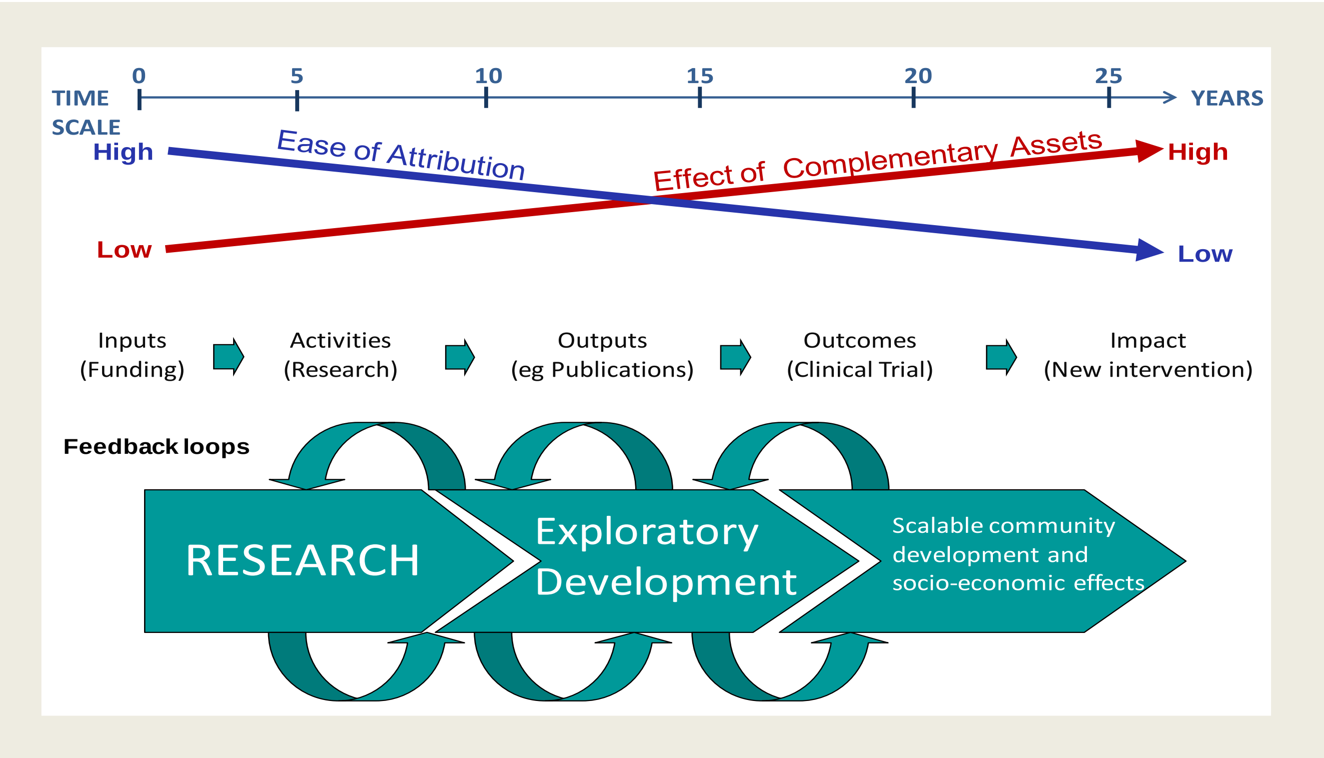
Source: Hughes and Kitson (2012)

Note: Respondents were drawn from all disciplines in all UK higher education institutions and could record interactions in each of the pathways shown.

To measure impact, therefore, you have to measure the health of the innovation system. Instead of return on investment, we propose trajectory measures that will provide a clear sense of a positive direction of change and which benchmark systematic success across the various stages of the innovation process. The formula for the allocation of Higher Education Innovation Funds from the Higher Education Funding Council for England already includes trajectory measures, such as strengthening and developing networks of innovation and forming strategic partnerships, and these provide a good foundation for broader use. Furthermore, the new Research Excellence Framework, which allocates funding based on impact, inherently provides benchmarks for long-term trajectory measures of the health of business-university collaborations.

There are clear positive returns on investment for public sector R&D[xv], but these are not the product of a simple linear pathway that flows from funded inputs to funding impact. Instead, research proceeds through feedback loops, failures, breakthroughs, setbacks and financial challenges before it becomes a commercially developed product. And along the way, success is the product of many parents. In particular, as Exhibit 4 demonstrates, the impact of complementary investment of time, intellectual input and money from business grows as the public investment in invention is matched by firms' pull-through into applications.

Exhibit 4: Time, Attribution, Impact



Source: Hughes and Martin (2012)

As we note in our recommendations, developing appropriate benchmarking trajectory measures across these pathways, disciplines, and technologies, and for different sectors, should be an urgent priority for the funding and research councils, as well as the proposed National Centre for Universities and Business.

For example, it may be more important that academics engage with creative and digital SMEs through informal advice and networking, rather than by forming new firms via spin-outs or through licensing technology; or that joint publications and joint science consortia are more important to pharmaceutical companies, which employ top scientists who work as equals on research problems with their university colleagues.

To understand such sectoral systems of innovation, we commissioned research on the pharmaceuticals, energy, creative-digital-IT (CDIT),[13] and construction sectors. These were chosen because they have different industrial structures (concentrated to diffuse), varied reliance on innovation (moderate to intense), varying speeds of innovation (long-run to rapid-fire), and different approaches to collaborative behaviour (strategic versus sporadic). See exhibit 5. To deepen our understanding of these characteristics and their impact on generating value, the UK Innovation Research Centre conducted a programme of in-depth interviews with a sample of 71 top-level sources from large and small firms, universities, government, regulators and charities.

13 CDIT was an acronym coined by a previous CIHE task force to encompass the converging nature of these industries and their innovation systems.

Exhibit 5: Industrial Sector Characteristics

Bio-Pharmaceuticals	Construction
Size: £30bn+ turnover Employees: 75, 000 Structure: Concentrated Approximately 350 companies, with fewer than 20% of firms employing nearly 90% of total workforce and the top 37 companies accounting for approximately 83% of total turnover. Collaborative approach: Consistent Technology Solution clock-speed: long run	Size: £122bn Employees: 2.1m Structure: Overall diffuse, but varying with market segment in a fragmented value chain. Overall 256,441 construction companies, but the total turnover of the top 100 biggest builders in the UK was around £64bn in 2011. Collaborative approach: Sporadic Technology solution clock-speed: Medium run
Energy	**CDIT**
Size: £49bn+ Employees: 173,000, the UK oil and gas supply chain, support services, supports employment of 407,000 people in the UK, around half in Scotland. Structure: Concentrated Six vertically integrated companies in electricity dominate both generation, 67%, and supply, 99%. Four oil companies account for the bulk of oil production. Renewables: diffuse. Collaborative approach: Consistent Technology solution clock speed: Long and medium run	Size: £102bn gross value add Employees: 2.5 million including freelancers Structure: Diffuse Some major players, but tens of thousands of small businesses, e.g. 485 games companies, 11,000 film and TV companies employing c. 154,000 people, 330,000 "software professionals" and 64% of software businesses employ fewer than 50 people. Collaborative approach: Sporadic Technology Solution clock-speed: long run: fibre, servers, platforms, and rapid-fire: user-interfaces, software, design.

Sources:

HM Government (2011) ' Strengths and Opportunity 2011: the landscape of medical technology, medical biotechnology, industrial biotechnology and pharmaceutical sectors in the UK.' December.

CIHE (2010) ' The Fuse: Igniting High Growth for Creative, Digital and Information Technology Industries in the UK' . September.

DECC (2010) Energy Market Assessment. Constructing Excellence (2011) UK Industry Performance Report 2011. The Construction Index Top 100 2011

Innovation and Collaboration in Four Sectors

Core Messages:

- Universities are playing an increasingly important strategic role in sector-specific innovation.
- Many big companies are developing fewer but longer-term strategic partnerships with universities, particularly for science-based business, and the decision as to which country to form these partnerships with is made at global board level.[14]
- Open innovation is an increasingly important means of developing new products and services across all sectors, and vitally so in pharmaceuticals.
- One-way models of technology or knowledge transfer between business and university always fail to capture the richness and value-creation possibilities of this relationship. Furthermore, they do not capture the processes and competences needed to manage this collaboration effectively, smoothly and speedily.
- Innovating for the grand challenges requires cross-disciplinary, cross-institution collaboration.
- Each sector requires a mix of policies and collaboration approaches relevant to their industrial structures, and therefore trajectory measures must be developed that are appropriate to each sector.

There were individual challenges in each of the sectors, but before we turn to those and to the issue of sector-specific innovation, we present five cross-sector observations which our research identified about the UK innovation system.

i) Collaboration is a resource-intensive activity on both sides, and financial resources represent only part of the exchange between industry and the research base.

Successful collaborations rely on investment; in the time spent on joint work and in the exchange of ideas, materials or tools.[15] This involves the development of an understanding of the institutional framework in which partner organisations operate; a shared vision of the objectives for the collaboration; and trust, clarity of motives and transparency in conduct.

As well as maturing university and academic behaviour, partnerships have been improved by better understanding in industry of how to manage the relationship and how to gain value from it. Progress is inevitably uneven – both on the university side, with different institutions, disciplines or research groups making more or less progress, and from industry, where traditional sectors such as automobile, aerospace and pharma, and new industries such as CDIT, are progressing at different speeds.[16]

> *"We stress the importance of academic freedom in attracting the best Principal Investigators to work on industry challenges. We have set up our various open institutes that way and it has been a critical learning for us."*
>
> Energy Executive

> *"When I talk about partnership, we are not just handing over money; we are putting intellectual input into the collaboration. We are intellectually invested."*
>
> Pharmaceuticals Executive

14 See BG Group case study, p.41. This exemplifies how boards make global decisions about where to do R&D, and reveals the role of the Brazilian government in stimulating their knowledge-economy.

15 See the Caterpillar Case Study p.42.

16 A recent review conducted by the CIHE and commissioned by the Technology Strategy Board and the Research Councils clarifies how the various players, mechanisms, underpinning systems and processes within the Knowledge Transfer Partnership (KTP) programme contribute to the success of individual KTP partnerships and projects. (See Ternouth, Garner, Wood, and Forbes 2012).

ii) Businesses and academia have different institutional objectives and timeframes, and collaborative success flows from understanding and reconciling the two cultures.

> *"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."*
>
> CDIT Executive

Academic incentives, especially promotion criteria, are still built mainly around publications and successful grant proposals rather than industry collaborations or industry experience. This hinders labour mobility between industry and academia even where industry expertise would be useful in research, education or commercialisation activities.

> *"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."*
>
> Senior Academic

When opportunities for rapid response research projects arise, universities cannot always respond, because they work on an annual workload allocation for teaching and research. Money in does not always result in contributions out in a fast and effective way. Nor is staffing flexible enough to move people around quickly. The EPSRC and other organisations are trying to respond to this, for example with Impact Acceleration Accounts. These provide flexible funding for universities, which some are using to provide staff time to deploy quickly to address arising business challenges.

iii) Critical barriers to commercialisation of academic research involve the management of intellectual property rights, financial constraints and lack of business know-how.

For many businesses, particularly big companies, IP is less of an issue than it was because of the growing realisation in universities that grants, contracts and consultancies are considerably more valuable.

> *"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."*
>
> Business Executive

But for others, particularly smaller companies and in emerging collaborative sectors, the challenge of simplifying IP negotiation remains a barrier.

> *"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

iv) Cross-disciplinary R&D is vital to addressing the grand challenges of the future

In universities, a silo mentality may discourage interdisciplinarity and hinder the ability to address grand challenges such as smart cities or climate change. This has been recognised by cross-disciplinary initiatives supported by the Research Councils, the Higher Education Funding Councils and the Technology Strategy Board, and by many universities off their own bat, but remains an enormous challenge for the future.

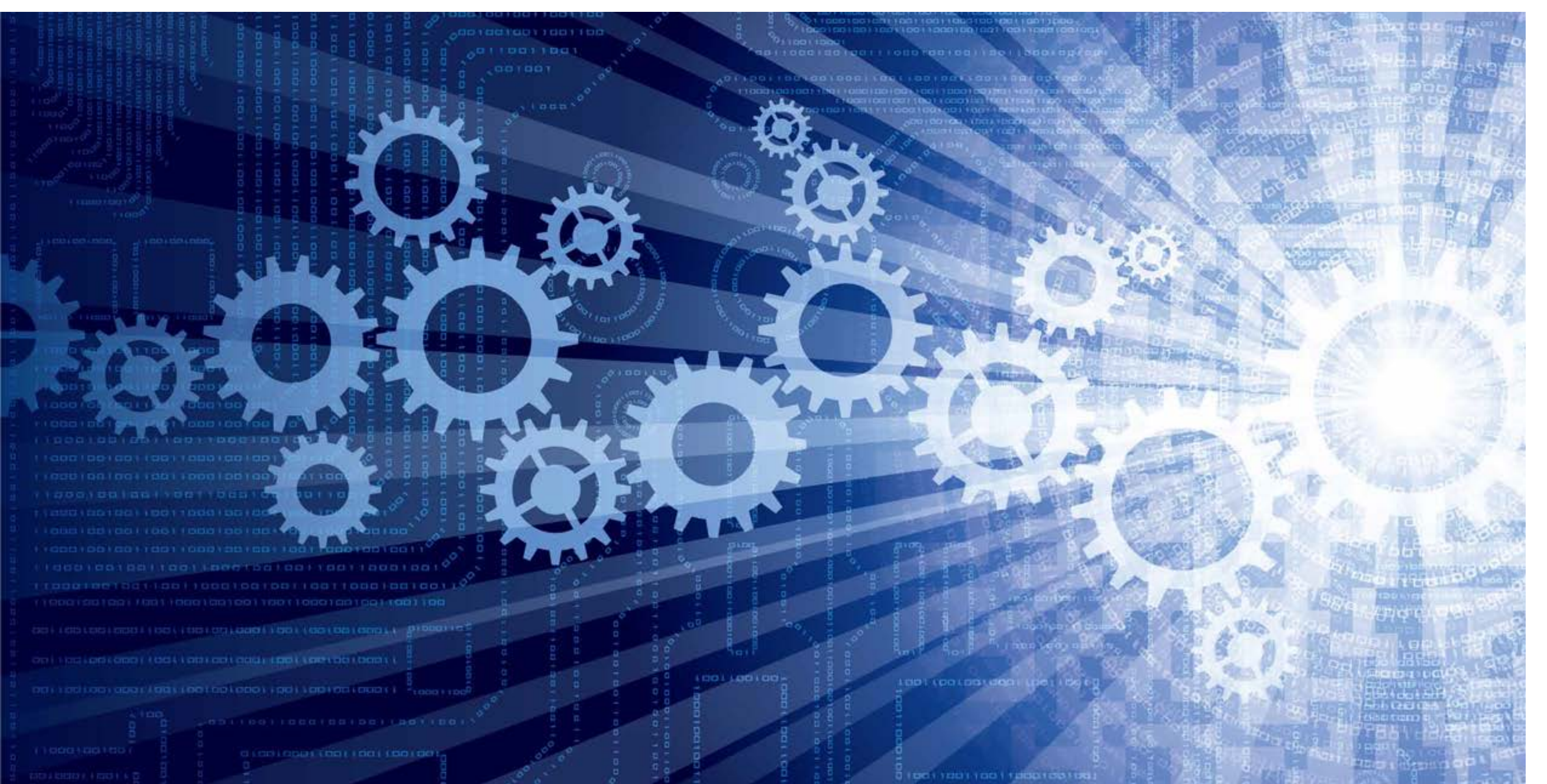
> *“We still have to break the university department silo mentality of problem-solving and functional excellence within a multi-disciplinary environment. It’s clear to us that to solve some problems we have to work across boundaries. Some universities have really woken up to that and have integrated 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.”*
>
> Pharmaceuticals Executive

v) The conservative attitude to risk among both investors and academics emerged with some regularity as a barrier to innovation and the creation of value.

There is a shortage of early-stage innovation funding, attributed in part to the current macroeconomic framework but mainly to the poor appetite among investors for first and second stage funding in some sectors. The British Venture Capital Association reported that in 2011 only 6% of its members’ funding went into seed capital, and 7% into start-ups.[xvi]

> *“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.”*
>
> Pharmaceuticals Executive

> *“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 Executive



Innovation, Collaboration and Industrial Strategy

The role of government remains a significant issue for many respondents to these interviews. There is a free-market school of thought that the role of government is to have no role; but successful innovation systems across the world have always had strong government input, both financial and strategic. Silicon Valley, the most famous cluster of all, and the source of hundreds of billions of dollars of value, was built on federal – mainly defence – funding of semi-conductors, software and the Internet. Without such investment, and federal dollars carrying these industries through the 'valley of death', the commercialised World Wide Web may never have happened.

The senior business leaders in our research felt there had been a number of missed opportunities by and for UK plc, particularly due to risk aversion among public sector officials, and the perceived weakness of government in formulating coherent long-term strategies that would enable businesses to implement long-term investment plans.

> *"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

This is not so much about picking winners, but instead involves choosing sectoral races and placing innovation bets, and supporting those bets by ensuring that the sectoral innovation system is well-understood, coordinated, supported and integrated. As the following CDIT executive notes, joined-up thinking creates a platform for innovation.

> *"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 Executive

Winners don't train themselves. There is a clear need for an approach to sectors and technologies which recognises the fine-grained understanding required to provide a stable framework that encourages firms to commit more to R&D. This also involves broader forms of fresh thinking and investment in intangibles such as software, skills, training, design and marketing.

Many respondents in the research felt that industrial strategies are required to pull through commercialised research based on university inventiveness into firms and the economy, particularly in key areas, such as advanced manufacturing and smart cities. These should be underpinned by long-term policies which ensure the participation of UK-based companies. This means supporting home-grown technologies and solutions, but also improving the capacity of UK-based firms to exploit technologies developed elsewhere.

> *"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 least, is incredibly important. And incentives to help translate things out of academic into the early phase companies. Any incentive that can help that is useful."*
>
> Pharmaceuticals Executive

There was also a general frustration about bureaucracy, and in particular about the need to manage Brussels and the European Commission more effectively.

> *"[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, 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 Executive

Finally, and crucially, the channels that facilitate collaboration between innovative SMEs, the research base and government are still seen as not being sufficiently effective. Our respondents felt that this had to remain a significant area of focus. We acknowledge the significant effort put into this area by government agencies, funding and research councils, and the Technology Strategy Board

> *"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."*
>
> Energy Executive

Sector-specific Innovation, Collaboration and Industrial Strategy in Four Sectors

We have made much in our recommendations and analysis of the need to support sector-specific innovation with appropriate measures and innovation systems. Each of the sectors we chose had different problems. If we are to collectively develop appropriate strategies that respond to these distinctive challenges, we need to develop coordination frameworks that help design the appropriate balance of fiscal and monetary incentives, and which ensure effective pathways to impact from the science base.

The following insights on sector strategy draw on the interviews in our sample, and subsequent engagements with business and university leaders. It is a work in progress and will be taken further by the CIHE in partnerships with others. The sections are intended to be exploratory rather than exhaustive.

Pharmaceuticals and Biotech

A key issue for pharmaceutical companies is the renewal of the industry's research and business models. As GSK note in their case study:

> *"It is not a secret that the fully-integrated pharma R&D model is out-dated and needs to change. The productivity levels of the past fifteen years are proof that the pharmaceutical industry has to reinvent its business model, become more efficient, and find higher potential, fledgling ideas to turn into life-changing medicines."*

In consequence, the sector is increasingly externalising R&D that was previously done in-house. A higher level of outsourcing and collaboration brings greater opportunities for independent R&D providers, smaller firms and universities. The complementary challenge is to the growth of a dynamic and well-supported biotech community in the UK, with potential for strong contributions from entrepreneurial academic teams. As one of the respondents in our research noted:

> *"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

GSK has invested heavily in this idea with the Stevenage Bioscience Catalyst, and is investing more generally in open innovation clusters:

> *"This is one of the true advantages of clusters where different approach and knowledge are brought together in a powerhouse of problem solving. We would like the boundaries between Academia, the NHS, Biotech, Research Institutes and Pharma to become much more porous so the ecosystem can develop. But this can only be achieved if all parties are well represented. Within the cluster we have some of the world's best specialist hospitals, institutions and universities, and we need to encourage biotechs to grow."*

There is a range of different initiatives that we note, such as the Cell Therapy Catapult, the multidisciplinary Francis Crick Centre, the Biomedical Catalyst Fund, and the new regulatory approaches to drug development, such as the Early Access Scheme for 'breakthrough drugs'. We would caution, in the light of the work of the Task Force on the role of big companies in the innovation system, that much of government's life science strategy is predicated on the role of SMEs. As drugs become more specialised, those SMEs – even if they are privately funded - are more likely to be inside the supply and value chains of the major pharma companies. It is crucial to join up this strategy, adding collaboration with the NHS, private health care providers and insurance companies.

Furthermore, if a UK bioscience cluster is to rival those of Boston and the San Francisco Bay Area, there are infrastructure problems which the major pharmaceutical companies on the Task Force point to as crucial. They include the difficulties of gaining planning permission for plant and buildings, terrible transport connections between Oxford and Cambridge, and the need for government coordination of high performance computing. This is an issue about strategic planning for the economy that goes beyond university-industry collaboration.

The metrics of successful university-business collaboration for bio-pharma in an open innovation environment are likely to show increases in the joint-problem activities we identified in Exhibit 3, namely: informal advice, participation in research consortia, joint papers, prototyping, physical plant co-location, and contract research.

The pharma challenge will bring together the thirty companies which account for most of the turnover, the ten universities which do most of the research in this area, the NHS and private providers which do the bulk of the procuring, and the supply chain of small innovative companies.

Creative, Digital and IT (CDIT)

The CDIT sector is emerging like a thousand archipelagos slowly becoming a continent. Its birth has been so rapid, and its growing pains so racked by booms and busts, that government systems can barely describe it, let alone measure it. It comprises tens of thousands of small businesses, hundreds of thousands of freelancers, and a smattering of UK-originated platform companies such as ARM. Furthermore, it encompasses the UK branches of global IT and Internet companies such as Google, Oracle, IBM and Cisco, world-leading creative companies, such as the WPP network, and a colossus in the BBC. The platforms built by the major IT and software companies provide the development space for shoals of smaller companies to build value, which in turn push those platforms to the point where they are rebuilt and create yet more value.[18]

In CDIT there is a growing recognition of the need to engage with universities. Many companies, large and small, now realise that they do not have access to all the science they require if they are to develop an outward-facing approach to the digital economy.

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

18 See Cisco Case Study p.39

"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

To understand CDIT, you have to measure it properly. The categories by which the gross value added of the creative and digital industries is measured within government are grossly out of date. The Brighton Fuse project, which was spawned by the CIHE project on CDIT, demonstrates that at least forty per cent of the businesses self-identified as CDIT companies do not appear in the government classification system. To fail to measure the innovation system is to fail to capture it.

Unlike the automotive industry and life sciences, CDIT is not represented coherently in government because it crosses over DCMS and BIS. A more coherent approach must be taken by government to ensure that developments in e-infrastructure and high performance computing are taken up by industries such as post-production, animation and film services, where we have thriving firms, as they are already by the health and energy sectors.

The core issue for most of the companies is their lack of Intellectual Property or other exploitable assets that will enable the businesses to grow from SMEs into larger businesses. Only 3% of the companies in Brighton possessed exploitable IP.[xvii] A key role for universities is to work with these companies, the TSB Creative Economy Catapult, and the Research Councils' Digital and Creative Economy Programmes, to increase their volume of IP. This might involve joint technology development, spin-outs, business support or work placements for PhD students. And all parties – including businesses - must ensure that their IP arrangements and negotiations are not lengthy and off-putting.

Appropriate trajectory measures for collaboration in CDIT are both long-run and close to market. The first group might include joint papers and research consortia on topics such as fibre or server technology. An example is the Cisco British Innovation Gateway (BIG) initiative.[19] The second might involve increased consultancy, sand pits, technology exhibitions and business services.[20]

Energy

All nations want secure, sustainable and affordable energy. The reality, however, is that this combination rarely exists on a national basis. In the UK Energy Sector the need for innovation is being driven by a number of factors:

- Fossil fuels are in effect concentrated sunlight, and as such have a natural advantage over most forms of renewable energy (except hydro and nuclear) in terms of cost of supply. This is exacerbated by the capital intensity and durability of energy supply assets. They last for decades and have a low marginal cost of supply.
- The easier it is to store and transport energy forms, the more global the market. Markets for oil and its derivatives are global, whereas markets for gas and in particular electricity are more local.
- The energy industry integrates a broader array of technologies into its activities than many, if not all, other sectors - including nuclear physics, geology and biotechnology to name but a few. Nonetheless energy supply, distribution and consumption remain notoriously inefficient, particularly in respect of the UK's aged domestic housing stock.
- The UK's oil, gas and coal industries are mature, and hence are declining as uses of natural resources.
- Many of the UK's nuclear power stations are nearing retirement and the UK has not yet committed to refreshing and enhancing its nuclear power capabilities.
- In response to climate and broader sustainability concerns, the UK has legislated for an 80% decrease in fossil carbon emissions by 2050, ahead of any other nation on Earth.

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19 See Cisco Case Study p 39.

20 The £5m ERDF London Creative and Digital Fusion programme brings together the CIHE, the Work Foundation, London universities, and the Arts and Humanities Knowledge Exchange Programme at Queen Mary's to run a programme like this for London SMEs.

These circumstances give rise to twin challenges for the UK. The first is the need to (re)develop the skills base needed to manage the transition to a more sustainable energy system. The second is to invent new energy technologies which can compete with fossil fuels without subsidies, without which the UK may be disadvantaged against other nations. The sums at stake are huge - perhaps 1% of GDP over the period to 2050 - but on the flipside, the UK has an opportunity to leverage any innovations into the global energy system.

There are many energy innovation coordinating bodies at the interface with government – for example the Committee on Climate Change, the Office for Renewable Energy Development, the Low Carbon Innovation Coordination Group and the Energy Research Partnership – and there is a growing capacity for quality analysis, for example in the UK Energy Technologies Institute (ETI) and the Department of Energy and Climate Change itself.

The government's response to the innovation and R&D needs of UK energy businesses – and of the UK energy system as a whole – inevitably has to balance the threats of climate change against the possible off-shoring of manufacturing to places where there is no price on carbon. It is crucial, therefore, that government have access on a systematic basis to senior energy leaders and academics to ensure long-term consistent policy-making.

Knowledge exchange between the energy industry and the public research base is well-established, through groupings such as the ETI, where applied research and demonstrations are carried out, as well as through bilateral arrangements between companies and universities. Industry involvement ensures communication to the academic community of the sector's needs, but contact between academia and policy makers still appears more limited than it might be.[xviii]

There is good evidence, however, that energy businesses are increasingly regarding their relationships with universities in a more strategic way, and that they are looking for long-term interactions.[21]

> *"We have a big programme to form closer links to universities to get good connectivity, good expertise that we don't have in-house."*
>
> Energy Executive

Furthermore, there is trend towards a greater concentration on fewer, more strategic partnerships.

> *"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

And this focus on deep relationships is spreading into expectations about commercial negotiations.

> *"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

> *"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

However, despite this commercial focus, there is a clear sense that the problems in energy are often long-run and require what Stokes would call both pure and user-inspired basic research.

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21 See BP Case Study p.38.

"...the challenges of refinery and chemical plant technology are a fundamental plank to how we address the world's energy challenge for the next fifty years."

Energy Executive

"It's good in some ways that there is still this difference (between academic and industry research), 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

In conclusion, the most effective trajectory measures for the energy sector should be: strategic partnerships with universities, research councils and the TSB, focused on fundamental science and engineering knowledge exchange and the engagement of academia, industry and the public sector in informing policy development for the energy sector.

Construction

Many components of the construction sector's value chain work on the basis of the lowest development cost, operate under conditions of frequent conflict, suffer from low, unpredictable profitability, and invest relatively little in training or innovation. Firms are organised on 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 are dependent on the efficient functioning of the entire project network rather than on a single firm, which often makes system integration a key aspect of innovation in the sector.[xix] 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.

"Innovation" within the construction industry is generally not associated with R&D activity. Patenting 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. Mass production techniques such as modularisation and pre-fabrication are being adopted slowly.

Whereas on-site innovation and learning do 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 is related to site specifics as well as client preferences, which 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 on price.

All of which leads to significant challenges for university-business collaboration.

"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

There are significant barriers to collaboration with universities among both the clients of the construction industry and the constructors themselves. These include management, leadership and culture. However, these attitudes are changing under the combined impact of climate change and financial pressures.

"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". Now we are asking 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."

Construction Executive

The increasing desire and need for the construction industry to increase its engagement with universities should lead to increases in the whole range of problem-solving trajectory measures, such as informal advice, research contracts, external secondments, consultancy services, and shared physical space.[22] The measures would include rises in pre-competitive collaboration between companies and universities, secure research environments to enable cooperation on clusters of problems, sandpits and advice to open up the innovation challenges, and vitally R&D collaborations must be part of the procurement process for major government infrastructure projects. Innovation has to be included in the specification for flagship construction developments to enable the industry, working with intermediate organisations and universities to take new innovations over the 'valley of death'. Finally, there should be increasing collaborations between non-engineering disciplines and the construction industry, for example through harnessing insights in behavioural sciences to stimulate more sustainable, rather than cheaper at point of sale approaches to procurement and construction.

Conclusion

Following the 2003 Lambert Review[xx] of business-university collaboration, and the willing engagement of government, funding and research councils, and university management teams over the past ten years, there is no doubt that many business leaders and academics feel that relationships have become better. They are more focused and strategic, and culturally healthier. However, these relationships must be encouraged to evolve and develop to ensure they become ever more potent, embedded, measured and relevant to the ever-fluctuating economic circumstances of the 21st Century. To paraphrase Schumpeter: stationary innovation systems are a contradiction in terms.

22 See Costain Case Study p.43.

Case Studies in Collaboration

Each study was authored by the company

GlaxoSmithKline Biomedical Cluster

It's not a secret that the fully-integrated pharma R&D model is out-dated and needs to change. The productivity levels of the past fifteen years are proof that the pharmaceutical industry has to reinvent its business model, become more efficient, and find higher potential, helping fledgling ideas to turn into life-changing medicines. GlaxoSmithKline recognised several years ago that it does not have the monopoly on innovation and has set about forging stronger links with biotechs and academia, where there are creative ideas and early stage assets which need help to translate them into medicines for patients. Government health organisations are also pursuing excellent and specialised research, leading the world in many fields, which is advancing our understanding of disease. Playing to each other's strengths and combining our efforts is the way forward for patients.

GSK has learned that you need to become part of the science environment, sharing ideas and great science, as well as entering the debate on how to move forward in the fight against disease. It has made great strides in the past few years and is now involved in several pre-competitive research initiatives as well as opening up its own doors by sharing compound library data, in particular for the benefit of the diseases of the developing world.

> *"I joined GSK from academia. I saw great science being carried out, but I also saw a company that was a bit closed off from the world. I wanted us to be more integrated in the science environment, especially as it was there on the doorstep."*
>
> Patrick Vallance, President, Pharmaceuticals R&D, GSK

Working together of course is a lot easier when you are near each other. GSK is a global organisation with more than 10,000 people in R&D, based in the UK, the USA, Spain, Belgium and China. We access ideas all over the globe, but we have some of the best universities and medical research centres within a stone's throw of our UK-based major research complexes. GlaxoSmithKline's R&D sites at Stevenage, Ware and Harlow are within the geographical triangle of Oxford, Cambridge and London and happily positioned in the middle of some of the world's best research. It would be folly not to collaborate with some of the best scientific minds who can apply their thinking to our common problems.

> *"We are looking for new medicines for diseases of the eye. All our research is conducted externally with groups like the Moorfields Eye Hospital and the Institute of Ophthalmology, University College London. Working with some of the world's top scientists in this area has resulted in ophthalmology becoming a key disease area for GSK in a very short period of time."*
>
> Claudine Bruck, head of Ophthalmology

Likewise GSK wants to work with biotechs and has a lot of depth and experience in turning concepts into medicines a patient can take. SMEs have entrepreneurial scientists who may have one or two areas they specialise in, but can only take their ideas so far. GSK is very happy to partner to take the ideas forward, but by setting ourselves up to work in close proximity with these teams of scientists there is even greater potential to spark new ideas. This is one of the true advantages of clusters, where different approaches and knowledge are brought together in a powerhouse of problem solving. We would like the boundaries between academia, the NHS, biotech, research institutes and Pharma to become much more porous so the ecosystem can develop. But this can only be achieved if all parties are well represented. Within the cluster are some of the world's best specialist hospitals, institutions and universities, and we need to encourage biotechs to grow. That is why GSK, the Wellcome Trust and Government have supported the creation of a Science Park co-located with GSK's R&D Centre. The Stevenage Bioscience Catalyst (SBC), the UK's first open innovation bioscience campus, opened for business in February 2012 (http://www.stevenagecatalyst.com). Within a few months of the science park opening, the University of Cambridge announced it would base researchers at the SBC to embark on a programme of scientific open collaboration with GSK. There are science parks in Cambridge already but the chance to work with GSK, and the proximity of the site to the rest of the South-East cluster, was too good an opportunity to miss.

This is one very visible example of the government's support for science and technology in the UK. We have been fortunate that the funding has been healthy and maintained over the past few years. The government clearly recognises that science and medicine are a long game and has been very supportive of initiatives to grow the UK's presence is areas such as biotech through seeding money and facilities.

As part of this growing cluster all parties are beginning to see the advantages of co-location – close enough in some cases to walk in and out of each other's premises; to have staff rotate into positions to get a different perspective; and close enough to form strong foundations that will sustain investment and attract other leaders in their fields to move to the area. The stronger the cluster, the stronger the individual entity. Clusters can become magnets for talent and expertise, which brings softer benefits such as a sense of belonging to a scientific community and the ability to move across the sectors.

"Living in an area where there is world class research makes it a great place to build your career while at the same time bringing up a family. It gives a sense of security to know that there are lots of opportunities in the area. Some of my friends from GSK are now working for Biotech companies nearby and they haven' t had to relocate to do it."

Jamie, Chemist

Why struggle alone when you can work together?

Why struggle alone when you can work together? And why not capitalise on the proximity of academia, industry and biotech?

If we get this right the ultimate beneficiaries are ptients. Scientists, whichever direction they come from, whether it is academia, biotech or industry, all want to make a difference to people's lives. Our learning is that GSK should be an integral part of bringing together others who have a common goal

Image courtesy of GSK

Rolls-Royce UTC network

A network of Rolls-Royce University Technology Centres (UTCs) lies at the heart of the company's long-term approach to developing technologies, helping to deliver the company's vision and to secure competitive advantage.

The global UTC network is part of the company's integrated approach to research and technology, and works closely with its highly focused strategic research teams, company technology specialists, and business leaders to identify and develop the new technologies required for its broad portfolio of products and services.

The company derives considerable value from this approach. Formalised, long-term relationships with UTCs offer the company much more efficient access to high-quality research, allow the development of deep and long-lasting relationships based on trust, connect the company with the wider academic world, and provide a mechanism for training and developing the next generation of experts.

The UTC model is highly-regarded and widely recognised. It has developed over two decades and is widely regarded as a prime example of an effective relationship between industry and academia. Initially concentrated in the UK – the first were set up at Imperial College and Oxford University in 1990 – today's international UTC network reflects the company's increasingly global footprint. There are 19 centres at 14 UK universities, four at German universities and others in Italy, Norway, Sweden, the US and Korea. Further relationships are in development.

> *"Unlike our major competitors, Rolls-Royce does not have a large corporate research centre. Instead, we have made our selves totally dependent on our University Technology Centres for our future technology. Our global university partners more than rise to this challenge"*
>
> Ric Parker, Rolls-Royce Director of Research and Technology

Each UTC is led by a senior academic with a global reputation in their field. They are supported by academics, research fellows, research assistants, technicians and a cohort of students undertaking PhDs and other higher degrees. Over 600 people are working in the UTC network at any one time, with over 400 PhD students being supported by Rolls-Royce through the UTC network.

According to Dr Jon Carrotte, Deputy Director of Loughborough's UTC in Combustion and Aerodynamics: 'The high-impact nature of applied research is a real boon to teaching.

> *'I can use fresh material in my lectures, and in addition welcome visiting professors like Ric Parker, Rolls-Royce Director of Research and Technology, to deliver unique and exciting insights into the technologies students are working on in the UTC – many of which could be in service use around the world in five-ten years time.'*

UTCs facilitate exchanges of people and knowledge.

Rolls-Royce offers a number of secondment opportunities to academics and students from UTCs, giving them the opportunity to work inside the company. The company also sends its own employees to work and study within UTCs, and a number of Rolls-Royce engineers have completed PhDs in this way. Staff from both sides have received Royal Society and Royal Academy of Engineering Industrial Fellowships allowing them to work on collaborative projects between science and industry. UTC staff and researchers publish around 400 technical papers annually, either independently or in conjunction with company engineers. Rolls-Royce applies for over 450 patents annually, with between eight and ten per cent of these resulting from our interaction with the UTC network.

Each UTC is 'owned' by an internal Rolls-Royce business unit. This is typically the engineering team of a supply chain unit seeking new technology and fresh capability to play a part in new product development. Each UTC addresses a distinct technical discipline, including noise, combustion, performance, aerodynamics, electrical systems, manufacturing, nuclear engineering, and many more. The technologies being developed undergo regular reviews and pass through formal 'gates' as they mature. A UTC will generally take development to the third or fourth level of technology readiness (TRL3/4) before a new technology is transferred to the company to conduct validation activity advancing it towards TRL6 through large and expensive rig and demonstrator programmes, at which point it can be utilised as a feature of new product designs.

Funding is provided through rolling five-year contracts, which enable UTC teams to take a long-term, strategic view of how to achieve specified research programme targets, agreed together with Rolls-Royce. Additional funding in support of fundamental and collaborative research may be provided from complementary sources such as the EU and, in the UK, the Engineering and Physical Sciences Research Council (EPSRC), the Technology Strategy Board, learned societies and regional agencies.

As a consequence of this long-term relationship, universities are in a position to make strategic investments to improve their scientific infrastructure and attract the most talented staff. For example, the Heat Transfer and Aerodynamics UTC at Oxford has recently relocated and re-equipped its Osney Laboratory, incorporating a new turbine research facility, at a cost of around £10 million.

> *'This would simply not have been possible had the university not had confidence in the continuity of our activity as a UTC,'*
>
> Director, Professor Peter Ireland.

There have been a wide range of successful research collaborations in recent years. One key area is materials research. With virtually all current commercial aircraft and much power generation plant using gas turbines, one challenge is to find radically new materials – beyond today's nickel-based superalloys – that will enable engines to run hotter in order to raise thermal efficiency, cut fuel burn and reduce harmful emissions.

The high-pressure turbine blade is one of the most demanding individual components, as it sits in the hottest part of the engine. Manufactured as a single crystal of nickel alloy to eliminate grain boundaries, they can run in gas streams with temperatures hundreds of degrees hotter than the melting point of the materials from which they are made. This is due to the refined alloys and single-crystal structure, the tough, specially developed coatings and the elaborate cooling labyrinths within the blade's core. UTCs have contributed significantly to all of these.

For the next generation of materials, the blue-sky vision and focused technical expertise existing within UTCs can generate significant results. The materials academic research team comprises Cambridge University, which drives high-temperature alloy research; Swansea University, specialising in the testing and understanding of mechanical properties and life-cycle capability; and Birmingham University, which undertakes materials process modelling and studies manufacturing issues such as alloy production and joining technologies. Additional capability is drawn from material specialists elsewhere, supported by the Rolls-Royce strategic partnership with the EPSRC launched in 2009.

With long-term funding, along with privileged access to data, tools and people, universities secure continuity and stability as well as the real-world technical challenges so attractive to high-class research staff. In return, Rolls-Royce stays directly connected to cutting-edge academic capabilities, with access to world-class skills and highly motivated staff.

Example the Trent 900 fan blade development

No fewer than six Rolls-Royce UTCs contributed technologies during the development of the swept fan blade for the Trent 900 that powers the Airbus A380.

- Birmingham's Materials UTC set to work characterising material properties. They measure and model resistance through fracture mechanics, enabling designs to be made that control the behaviour of cracks in non-uniform stress fields at elevated temperatures.
- The Solid Mechanics UTC at Oxford addressed the effects of 'foreign object damage' (anything entering the front of the engine, from large birds to runway debris) on the very large fan blade.

It developed models to understand and predict material behaviour under high strain-rate conditions, allowing engineers to design the blade to resist failure.

- Complementary research into blade integrity was undertaken by Imperial College London. The College focused on unsteady flow modelling, aeroelasticity, bladed-disc vibration with emphasis on non-linear behaviour, mistuning (to avoid resonance) and modal test planning.
- Research in the Whittle Laboratory in Cambridge developed a range of fan flow models. These were based on complex 3D flow calculations, validated through detailed experimental studies, that enabled a blade design embodying increased efficiency yet still tolerant to inlet distortion and providing sufficient surge margin for safe off-design operation.
- Other UTC inputs benefiting the Trent 900 fan blade design came from Southampton, which studied the flow effects on fan noise, introducing an acoustic liner to eliminate the fan tones that generate 'buzz-saw' noise; and Nottingham, which specialises in manufacturing issues, particularly fixturing and tooling for complex environments and processes, delivered tooling concepts now used in a more efficient blade production process.

No fewer than six Rolls-Royce UTCs contributed technologies during the development of the swept fan blade for the Trent 900.

Image courtesy of Rolls-Royce

BP Institute for Multiphase Flow - Cambridge

The BP Institute for Multiphase Flow was established by BP in 1999/2000 via an endowment fund of approximately £25m which created the building and funds six research staff, support staff and ongoing maintenance. The Institute conducts open research across a wide range of topics under the theme of multiphase flow and surface chemistry. The topics range from the microscale to ocean mixing, and involves industrial relationships from oil industry to paint and food.

BPI's key contribution to BP's wider set of objectives is the ability it provides for the company to access basic science reasoning and ideas, and to draw on insights from these to inform the way that addresses existing and potential challenges. In turn, the Institute can learn from the company's technical and business problems to further the boundaries and applications of its research.

The BPI has demonstrated that partnerships can be constructed that do not have overt commercial mechanisms but which can yield extraordinary results. Fundamental insights into surface science have translated into technology development and deployment, in enhanced oil recovery and in advanced automotive lubricants.

The key factors which have enabled the BPI to play the positive role which it is perceived to have done are:

- The scientific and corporate reputation of the Institute's founders, which have established the desirability and credibility of funding fundamental research as a way of developing insights of potential value for the company.
- The existence of a set of strong personal relationships, which greatly moderated the perceived risk of the investment when the Institute was set up.
- The long-term nature of the relationship on the basis of the endowment through which the Institute is financed.
- The demonstrated ability of BPI to augment the problem-solving capacity of BP by adopting new, insightful and first-principles thinking to problems arising in the day-to-day operations of BP.
- The development of trust at an institutional and individual level, based on repeated interactions.
- The provision through the BPI of the opportunity for academics to pursue a tenure-based career development path within a knowledge exchange setting. This has attracted excellent candidates to fill the posts endowed at the Institute, and facilitated the establishment of a very strong platform for interactions and research collaborations with those individuals and potentially with their wider departmental homes.
- The quality of individuals who have from time to time played the role of gatekeepers or boundary spanners linking BP to BPI.
- The BPI Director's leadership qualities, and the ability of Director and senior endowed post holders in BPI to engage with the company and display the capacity to understand and move with ease across the industry-university boundary.
- The variety of formal and especially informal mechanisms of interaction between the company and the Institute. These allow connections to be made which can lead to new projects.

Cisco, National Virtual Incubator

Case study: Cisco, National Virtual Incubator

In 2011, Cisco UKI made a major commitment to supporting the development the UK's digital economy, called the British Innovation Gateway (BIG - see www.ciscobig.co.uk). One of the major elements of the BIG programme is establishment of the so-called National Virtual Incubator (the "NVI").

The NVI initiative is based upon a very straightforward, but powerful, Cisco point of view: in the 21st century successful innovation cannot be entirely local. Cities, regions and nations that are striving to develop the innovative businesses that will drive economic growth and be the engines of job creation need unmatched capabilities to connect, communicate and collaborate with each other, both nationally and internationally.

When Cisco looked at the UK's "innovation ecosystem" it was clear that it possessed many world-leading innovation organisations and an established high-speed research network in the form of JANET (UK), but it was also apparent that there was a great deal of latent potential that could be unlocked through enabling more and better collaboration. This is an area where Cisco has global experience and capabilities that it wants to share with the UK through creating the NVI.

Purpose of the NVI

The NVI brings organisations together by creating a network of leading centres of research, innovation and business incubation called "NVI Nodes". These NVI Nodes will use a common platform of advanced video collaboration technologies to deliver entrepreneurship and innovation programmes and services to an expanding NVI audience. With the support of JANET (UK), these NVI Nodes will be located across the UK and will be linked to similar centres of innovation around the world. At the time of writing, Nodes are being established in Greenwich, Birmingham, Cambridge, Shoreditch, Manchester, Coventry and Dundee, with more in the pipeline.

Collectively, the organisations responsible for these NVI Nodes are known as the NVI Alliance. The NVI Alliance is not a legal entity, but a group of organisations whose members will use their NVI Node facilities to pioneer and promote new approaches to borderless, network-enabled, innovation.

Purpose of the NVI Alliance

The NVI will be implemented under the auspices of the NVI Alliance. The central focus of the NVI Alliance is to define and achieve a set of common goals that will support and expedite the creation and growth of start-up companies and small-to-medium enterprises (and/or social innovation initiatives; particularly, but not exclusively, those focused on network-enabled digital innovation with high growth potential.

Goals of the NVI Alliance

The goals of the NVI Alliance are to:

- strengthen the UK innovation ecosystem, particularly by creating greater access to and exchange of relevant ideas, expertise, skills, experience and funding;
- enable increased pace, breadth and depth of innovation through enhanced communication and collaboration;
- build partnerships to create and deliver programmes which support innovation and entrepreneurship;
- extend the opportunities and benefits of the Cisco BIG programme, and similar activities undertaken by NVI Members, throughout the UK;
- enable international links for UK innovation and research clusters, and associated organisations and individuals;

- accelerate the creation and incubation of start-up and SME-type businesses, particularly, but not exclusively, those focused around networked digital technology; and
- pioneer and promote new approaches to borderless, network-enabled, innovation.

The NVI is a not-for-profit initiative, and no fees or other charges are levied on NVI Alliance members. Cisco has taken it upon itself to provide video collaboration technologies to an initial set of nodes so that a critical mass of participating organisations can be reached as quickly as possible. Past a certain point, additional members will need to bear technology costs themselves. These costs are not prohibitive. Importantly, the open standards nature of the technologies in question means that choices are not limited to those provided by Cisco.

Although in its infancy, a critical message of the NVI for policy makers is that the UK already has a tremendous capacity for 21st century innovation, including the critical network infrastructure embodied in JANET (UK). Cisco has seen the incredible potential this infrastructure represents and, of its own volition, has directly invested to help JANET (UK) bolster its capabilities to support the wider innovation ecosystem. It is to be hoped that this decision by Cisco evidences the need for the UK to continue to nurture and publicly invest in this critical national capability.

Image courtesy of Cisco

BG Technology Strategy in Brazil

BG Group is building a significant business in Brazil through oil and gas reserves in the Santos Basin's pre-salt. Brazil is a key growth asset in the Group's portfolio, offering significant reserves, ease of access to world crude markets and a growing domestic gas market.

Based on BG Group's activity in Brazil, concession agreements have been put in place with the Brazilian Government for the sub-salt fields in Santos Basin stipulating that BG Group will allocate 1% of gross revenues from such fields to Research and Development (R&D) in Brazil. The 1% levy is a contractual obligation applied to all concessionaries whenever their oil and gas production surpasses a specific threshold by field. As a result, BG Group expects to invest approximately $2 Billion in R&D in Brazil up to 2025.

The Brazil R&D levy, as it is commonly known, is having profound consequences for how BG Group is implementing its global technology strategy. BG Group has actively embraced the opportunities that the R&D levy creates and has centralised key global technology activities in Brazil.

The construction of BG Group's Global Technology Centre (GTC) in Rio de Janeiro's Science Park is currently underway, with employees already working on global technology activities within the Group's existing facilities. The GTC will play a pivotal role in identifying technology challenges faced by BG Group in Brazil and in its assets worldwide. The Centre will work to source solutions to these challenges both from within Brazil and the rest of the world.

The GTC itself will not be a research centre: there will be no labs, no white coats. Rather, the Centre will source R&D projects with partners in Brazil. The R&D Levy regulations determine that at least half the obligation is spent within Brazilian Universities and Research Institutes, whilst the other half can be spent through industry and outside of Brazil. This includes, for example, private suppliers with many of these companies now establishing research facilities in Brazil.

The GTC will coordinate dedicated BG Group Institutes within Brazilian Universities and these will look at specific fields of interest (for example, Carbonate Rocks, Gas Utilisation, Carbon Management). BG Group is developing activities to bridge the academia-industry gap in Brazil and it is actively promoting partnerships to cover levy requirements.

Through its relationships with the Brazilian Government, BG Group understands the Government's priorities and is active in helping to establish public private partnerships in Brazil. For example, BG Group was the first company to announce its participation in President's Dilma flagship programme "Science without Borders", which aims to send 100,000 Brazilian students and researchers abroad. BG Group expects to contribute up to $100 Million to this programme and in implementing the partnership trainBrazilian researchers in leading Universities worldwide. The first cluster of Doctoral and Post-Doctoral students are currently being trained at the University of Aberdeen where they will focus on Sedimentology. BG Group and the National Council for Scientific and Technological Development (CNPq) will cover the full economic costs of this training. BG Group is encouraging long-lasting collaboration between UK Universities and their counterparts in Brazil.

BG Group is working in partnership with the Brazilian Government to ensure that the R&D Levy funds help to establish a broader oil and gas knowledge-base in Brazil. BG Group believes that utilising partnerships to implement the R&D Levy requirements will facilitate knowledge sharing and transfer, enabling the Brazilian industry to benefit from BG Group's investment in R&D.

Caterpillar and Loughborough University: Long term strategic partnership driving value for both organisations

Early years – a relationship with Perkins

The relationship with Caterpillar began in the early 1990's with a partnership between Perkins and Loughborough University, spanning research, graduate recruitment, and CPD for Perkins engineers. Perkins also sponsored a Chair at Loughborough in the engines research field. The relationship is based, therefore, on both excellent underpinning research capability and the supply of talented engineers.

An expanding link – becoming embedded in fundamental Caterpillar research

In 1997 Caterpillar acquired Perkins in a $1.3 billion deal. Crucially, the depth of engagement with Loughborough continued. An initially small Caterpillar R&D team was established at the Perkins Peterborough site, and began to collaborate in UK R&D. Caterpillar began to partner with Loughborough – and other companies and Universities – in multi-partner R&D projects (e.g. with EPSRC, DTI and EU funding). This was important for CAT to expand research activity and secure leverage. A series of research projects were developed in more fundamental areas of research that would drive future engine innovation to meet demanding emissions targets.

A team of researchers from Sussex, already engaged with CAT, relocated to Loughborough broadening the range of shared research interests. Links continued with Perkins, including CPD courses in combustion and engine design and at one stage more than 40% of Perkins graduate recruits were from Loughborough. Contacts were built with the main Caterpillar R&D facility in the US.

Consolidating a strategic partnership: The Caterpillar Innovation and Research Centre (I&RC)

Caterpillar needed to achieve greater scale and efficiency in research and this could not be achieved internally. A new model was developed with Loughborough – building on experiences with other partners (such as the Rolls Royce UTC at Loughborough). Caterpillar had also become a founding partner in the £1Bn Energy Technologies Institute public-private partnership, which also has its HQ at Loughborough. The I&RC allowed a portfolio of activities – ranging from long term, collaborative and co-funded projects through to short term directly funded work to be undertaken. It enabled the relationship to be managed and developed to derive best value for all parties

A clear framework was established in relation to IP, speeding up the contracts negotiation process dramatically. Significant leverage has been obtained for CAT investment in research – around 1.75 times. In parallel, developments continued on a range of "people related" areas – Caterpillar graduate recruitment, CPD, promoting STEM subjects.

For example in STEM, Loughborough hosted the first ever Science Summer School for the Thomas Deacon Academy, Peterborough. TDA is the largest single site City Academy in the Government programme and is sponsored by Perkins/CAT. Loughborough has been given "UK University Partnership" status by CAT UK, one of only five such Universities. This makes the University eligible to receive funding from the CAT Foundation.

Learning

Caterpillar has major engineering activities in the UK, employing more than 11,000 people. The engagement with Loughborough helps those activities remain competitive. Loughborough is now established as a leader in engines research and is levering the position to develop collaborations with other companies. At the heart of this successful relationship were organisations that could see mutual long term benefit in collaboration, and a range of people committed to making this work. Relationships are developed at the highest level (University VC; VP and CTO at CAT) and at all levels below. Both partners share a view that all aspects of their interaction should be included and managed as part of the process.

Costain, Building the Innovation Network

The most potent forms of industrial innovation through the 19th, 20th and 21st centuries have been driven, in turn, by the work of the inspired innovator, then the dedicated corporate research team and now the collaborative network. Costain's approach has been to embrace this change creatively.

Networks have nodes, in this case centres of research excellence, and they have connections. Costain's approach, while supporting the 'nodes', has been to focus on the connections, and in particular the chains of connections that lead to live trails and commercial exploitation. The best of these link customers, researchers, technologists, designers, specialists in the supply chain, business and joint venture partners and Costain's own business units. The aim is to create 'golden threads' which link the issue at hand, through those who hold the solutions (or the making of them), to those that implement. Success is a collaboration which delivers a better quality and better value solution to a societal need.

Success has come from building close relationships with universities at student, graduate and research levels. Examples for Costain are with Brighton, where there is a partnership programme on water engineering, at Cambridge, where Costain is working with the Engineering Department on wireless sensor technologies in tunnelling applications, and at Sheffield, where advances in agent-based modelling are being trialled in live, co-evolutionary environments to advance our understanding of a range of effects from transport network optimisation, public safety management and effective project procurement. There is exchange not only of ideas and technologies; secondments, recruitment and sabbaticals are all part of the mix. These programmes engage and extend to research bodies such as the Transport Research Laboratory and the Energy Technology Institute, to SMEs and specialist groups and to a group of industry customers. The engagement of the industry's customers is critical in the construction sector, as they are responsible for and understand the societal need that is served; they also control access to the infrastructure where change will be made.

Costain looks beyond the technical. Planning permission, driven by community acceptance of schemes, is one of the biggest constraints on the industry. Costain has worked with local communities to make schemes not only good enough to want once complete, but also through the disruptive phase of construction. The best successes have been in South Wales where a sequence of roads projects has been used to place the economically inactive into regular employment, to stimulate the local supply chains and to put trained construction professionals into local schools and community groups. Finance is another constraint; Costain is trialling new approaches to re-activate stalled schemes such as the A14 in Cambridge and is finding new ways to address local authority maintenance. These innovations in social science and business model are releasing new business streams and efficiencies across the public, regulated and private sectors. The 'golden threads' link departments of social science and business schools with artists, writers, financiers and lawyers.

So how does this sustain? Costain is clear that a traditional accountancy-led approach to business management, looking for simple relationships between action and return, is inadequate. The networked approach is more subtle: success can be measured only at the whole systems level, which, for Costain, is at the firm's bottom line. Whilst obviously failing initiatives are weeded out, and successful spin-outs and projects celebrated, effects such as staff motivation because they can innovate with researchers and partners, or the particular benefits of a relationship, can be too subtle to measure. But such complexity is home territory to the construction professional. While a well-run project is organised and linear in its execution, it is not so by nature. Taming complex systems is business as normal for the sector, and that positions it to make great strides in the new, networked era.

Endnotes

i. Foray and Lissoni (2009 p.282)

ii. Hughes and Martin (2012 p.13)

iii. Powering Up. Business and Universities Collaborating for Manufacturing Competitiveness. CIHE (2011 p.18)

iv. The Task Force reports are all available online:
The UK R&D Landscape, Hughes, A. and Mina, A., www.cihe.co.uk/RDlandscape.
Enhancing Impact, The Value of Public Sector R&D, Hughes, A and Martin, B. R. www.cihe.co.uk/impact.
Enhancing Collaboration, Creating Value, Business Interaction with the UK Research Base in Four Sectors, Mina, A. and Probert, J. www.cihe.co.uk/eccv-main.

v. The Small Business Innovation Research Program (SBIR), introduced in the United States in 1982, requires government agencies' (mainly Department of Defense, National Institutes of Health, NASA, National Science Foundation and the Department of Energy) external R&D budgets to set aside 2.5% of teir funds for the programme, which offers competition-based awards to small innovative firms in three phases: 1) (six months), $100 000 for a feasibility study allowing small firms to test the scientific and technical value of their R&D effort and its feasibility; 2) two years, $750 000 for a full R&D effort; and 3) the firm pursues – with non-SBIR funds – the commercialisation of the technology. Phase 3 follow-on projects can benefit from US government R&D funding; awards are then funded from mainstream budget lines.
The SBIR programme is worth over $2 billion annually and makes over 4000 awards each year. SBIR funds are designed as a first step on the procurement ladder. Awards are linked to public sector customer requirements. Historically, a quarter of the companies are first-time winners. The UK's SBRI programme was relaunched by the TSB in 2009/10 with around £40 million for a similar two-stage investment process.

vi. Wilson (2012 p.5).

vii. Macmillan, Siegel and Subba Narasimha (1985 p.119-128).

viii. PWC (2012 p.11). Also see Mina and Probert (2012, p.39).

ix. Schumpeter (1943 p174.)

x. Chesbrough (2003).

xi. For an extended version of this section, see Sir Richard Lambert: Can Britain Make it? Prospect Magazine September 2011

xii. Hughes and Mina (2012, p.24).

xiii. Hughes and Mina (2012 p.1).

xiv. National Academy of Engineering (2003 p.227).

xv. See Hughes and Martin, Docherty ed (2012 p.3) and Hughes and Martin (2012) passim.

xvi. BVCA Report on Investment Activity p.5

xvii. http://www.brightonfuse.com/

xviii. Mina and Probert (2012 p12).

xix. Mina and Probert (2012 p.15).

xx. Sir Richard Lambert (2003)

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