> Research for our Future:

UK business success through public investment in research

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RESEARCH COUNCILS UK

FOREWORD

Professor David Delpy, RCUK Impact Champion

Research Councils UK (RCUK) believes that strategic delivery of focused research programmes, alongside nurturing innovative basic research, is the key to fostering economic recovery, ultimately placing the UK in a position of leadership on the world stage of research and innovation. The Research Councils occupy a vital position in having a balanced portfolio of funding both excellent people throughout their research careers, and excellent projects that bring huge economic and societal benefits to the UK. Alongside this we invest in and provide access to a full range of world-class research facilities, both in the UK and abroad. For example the establishment of the Daresbury and Harwell Science and Innovation Campuses provides a unique environment for innovation and business growth. Each is a vibrant and growing community of science and technology-based innovation and enterprise. Over 4,500 people now work on the Harwell campus in some 100 organisations.

One of the most significant benefits to UK business of a strong research base are the excellent people with great ideas who work with our businesses, policy makers, innovators and entrepreneurs to deliver new, innovative solutions and products. Collaborative projects are a common mechanism for this, where there are shared interests. But for many research users the need is to bring such expertise directly into their business, thereby importing the capabilities and knowledge of a particular individual, along with their networks and background.

Therefore, to support fully UK business, the UK requires a sufficient supply of excellent, highly skilled researchers. RCUK has responsibility for making the largest single investment in researchers in UK higher education. In addition, RCUK actively works to encourage and enable the movement of researchers between the research base and research users, at every career stage and level, and in any direction.

RCUK is also proud that UK academics already have a phenomenal record of engagement with business, which will provide a vital platform for realising benefits from research and training for the future. RCUK directly engages with around 2,500 companies, with 21% of PhD projects having formal collaboration arrangements with business and industry partners. The strong reputation for quality and relevance of UK academics has resulted in over £2 billion of collaborative funding from UK business and industry since 2006 and in the last three years, almost £1 billion of inward investment can be directly linked to RCUK efforts to attract international funding into UK research.

I am delighted that this report demonstrates the value of academic research to business and industry across many established sectors, such as engineering and pharma, as well as to emerging sectors such as the creative industries. Some of the greatest long-term productivity advances in UK business come through breakthroughs in basic knowledge and, moving forward we will continue to support this so that publicly funded research continues to raise the productivity of R&D in the private sector. We believe that research is at the heart of the UK's long-term wellbeing and economic growth. The Research Councils will continue to build on their track record of excellence with impact to drive forward the UK's future prosperity and ensure that the UK has a productive economy, healthy society and can contribute to a sustainable world.

SUMMARY

Research for our future: UK business success through public investment in research

What contribution does scientific research make to innovation, productivity and long-term economic growth? Why does such a substantial share of a country's spending on research and development (R&D) need to be publicly funded, even in the United States? And is it really necessary for the UK to sustain the current level of public investment in research, particularly in straitened economic times – or can UK businesses and the UK economy 'free-ride' on research done elsewhere?

These are the questions explored in this report. The broad conclusions can be summarised as follows:

Research is our future

Continued public investment in scientific endeavour is essential for the success of UK business and industry – and, more broadly, for a productive economy, a healthy society and a sustainable world. Estimates of the impact of Research Council spending on the UK's national output suggest that a cut of £1 billion in annual spending would lead to a fall in GDP of £10 billion (Haskel and Wallis, 2010).

Research is a key driver of economic growth

The greatest long-term productivity advances come through breakthroughs in basic knowledge – and a substantial proportion of the R&D that creates new knowledge and leads to increased productivity is done in universities and other public research institutions.

Public R&D boosts private R&D

Publicly funded research raises the productivity of R&D in the private sector – through what are known as 'knowledge spillovers' – and encourages companies to do more R&D themselves. It also leads to inventions that can be commercialised through licensing to private companies or via the formation of new start-up companies.

Research has 'two faces'

Science is important for innovation and productivity not just for pushing forward the technological frontier. It also makes it possible for companies to learn about and absorb innovations from elsewhere, including the output of basic science. The UK needs to be doing frontier research to be able to take advantage of frontier research being done elsewhere.

Research institutions produce highly skilled people

Alongside new knowledge, universities working at the research frontier have a second core 'product', namely highly trained people, an essential resource for UK companies and foreign companies investing in the UK. Both outputs are essential for sustaining and improving the country's economic performance.

Research supports local economic development

The current high quality of UK research makes the country attractive for inward investment by international business and industry through collaborations and siting offices. Universities also encourage innovation by smaller local businesses and, through incubators and science parks, the emergence of new companies.

Speaking at the annual conference of Universities UK (UUK) in September 2010, Professor Steve Smith, vice-chancellor of the University of Exeter and president of UUK, summed up the evidence on public investment in research and the potential impact of spending cuts:

> **"All the international and UK evidence points to one inescapable conclusion: in R&D, it is governmental spending that leverages out private sector spending and is a magnet for private investment and for inward investment."**

> **"Reducing governmental R&D spending thus starts a vicious circle, leading not to replacement private R&D spending but to reductions in private spend. This leads to a downward spiral as charities and businesses react by moving their investment to our competitors."**

RESEARCH FOR OUR FUTURE

A broad consensus on the value of research

Understandably, most people in the research community would concur with these conclusions on the value of research to the UK economy. The Royal Society's report The Scientific Century, for example, says that evidence of the economic contribution of UK science is clear. But these conclusions also receive strong support from a wide range of other people, senior representatives from across business, industry, government and parliament.

They are echoed, for example, in reports from the Science and Technology Committees of the House of Commons and the House of Lords. And they are emphasised in investigations by two of the UK's most successful and innovative businessmen of recent times, Sir James Dyson and Dr Hermann Hauser.

Sir James Dyson's study for the Conservative Party concludes:

> "Many of the best new ideas are being created in university labs and the UK has far more than its fair share of leading universities... Blue skies research is critical if the UK is to develop high value added industries… The success of our high-tech companies has been achieved through a combination of a good grasp of blue skies research, creative application of research and entrepreneurial spirit."

And Dr Hauser's study commissioned by the previous government says:

> "Structured government support is an important element of the innovation system. It can facilitate the development of new technologies, help establish them in the market and encourage their adoption, drive economic growth and deliver other spillover benefits, such as the development of new skills."

While all these reports differ in scope, they are unanimous in their conclusion that sustained investment in the research base must be central to the UK's strategy for economic growth and recovery.

The two senior government ministers whose remit covers UK universities, UK science and UK business have expressed similar views. In a recent speech business secretary Vince Cable said:

> "How does government spending in scientific research contribute to the economy? There is a lot of evidence of the connection between innovation and economic performance."

> "Innovation, the introduction of new or improved products, processes or methods – has been shown to be the key driver of economic growth in advanced economies…. science, research and innovation are vital to this country's future economic growth."

And universities and science minister David Willetts told the annual conference of Universities UK:

> "A strong research base is vital for our future in a global knowledge economy: strong in both fundamental, curiosity-driven research and research applied to the challenges facing businesses and public services. Science and research are the lifeblood of many sectors, essential to growth and a rebalanced economy."

> "Such research not only pushes back the frontiers of knowledge but supports growth in the economy by boosting the performance of business, producing highly skilled people, improving public services and policy-making, and by attracting R&D investment from global business."

The value to business and industry of the innovation and skills that university research produces is also demonstrated by voices from the private sector and case studies of successful commercial and social outcomes of public investments in science summarised later in this report. The Confederation of British Industry (CBI), for example, has made the following call:

> "The government must protect investment in areas that do most to foster economic growth… The government should therefore prioritise spending on investment in infrastructure; knowledge assets such as research and development; and human capital via education and skills."

Public opinion is also strongly supportive. An Ipsos MORI survey in September 2010 shows strong backing from the general public for continued investment in higher education. The survey reports 90 per cent of respondents thinking that it is important for the government to invest in UK universities, and 89 per cent agreeing that universities contribute to advances in science, technology and healthcare.

The shared views of ministers, business representatives, scientists, researchers and the general public add up to a compelling argument for continued public investment in science and continued close collaboration between business and the research community to ensure that the UK has a productive economy and a healthy society, and contributes to a sustainable world.

Research spending and research performance

Investment in R&D is essential for developing and adopting new technologies and raising productivity. But for a number of years it has been far lower in the UK than in many other countries (Van Reenen, 1997; Nickell and Van Reenen, 2002; Griffith and Harrison, 2003). For example, in the United States, where 70 per cent of R&D spending is private, the intensity of business expenditure on R&D relative to GDP is comparatively high and has increased over the 1990s and 2000s. In the UK, it started lower and declined until the mid-2000s before beginning to rise slowly.

Several studies have highlighted the almost continuous decline in UK R&D as a proportion of national income from the early 1980s to the mid-2000s (for example, Baily and Funk Kirkegaard, 2004). In 2004, the UK spent just 1.1 per cent of GDP on business R&D activities compared with an average of 1.7 per cent for France, Germany and the United States. In 1981, the figure for the UK was 1.8 per cent.

In recent years, both public and private spending on research have risen steadily in real terms, increasing by 15 per cent in the five years to 2008, the most recent year for which data are available. Over half of the money comes from business: UK companies spend around £12 billion per year on R&D. Charities spend around £600 million.

The UK government spends around £10 billion on R&D. Publicly funded R&D consists of about 33 per cent spent on Research Councils, 33 per cent on defence R&D, 20 per cent on civil R&D (non-defence government departments) and the rest on support to university research, funding which is distributed according to performance as currently measured by the research assessment exercise (RAE).

Research Council funding is obtained by universities by competitive allocation. The funds are spent on paying for researcher time and equipment to support the discovery of new knowledge, which must be made publicly available. Of that Research Council money, over 90 per cent goes on engineering, natural sciences and medicine. Funding for social sciences and the arts and humanities is about 6 per cent of the total.

In terms of research performance, research is one of the UK's greatest success stories. The research base is the most productive among the world's leading economies and its overall quality is second only to the United States. The country ranks high in terms of publications per head of population – about 50 per cent higher than the European Union (EU) average and 16 per cent higher than the United States.

In terms of basic research, the UK ranks very highly: second only to the United States in terms of academic citations, accounting for an impressive 11.9 per cent share of total world citations (compared with around 1 per cent of the world's population). The country ranks fifth in the world for the number of PhDs produced per unit of higher education R&D spending. And UK researchers consistently win a high share of the world's major scientific prizes.

The UK currently ranks ninth among OECD countries in terms of public support for higher education in the form of grants to universities and Research Councils for research. This compares with a position of sixteenth in 1996. But the latest OECD figures show that the United States invests 3.1 per cent of GDP and the UK just 1.3 per cent, below the OECD average of 1.5 per cent.

Proposed cuts in research funding would lead to a substantial fall in the UK's competitive position as most other developed countries are responding to difficult economic times by increasing rather than decreasing their investment in science. The United States intends to double its scientific research budget between 2006 and 2016. Australia, Canada, China, France and Germany also intend to increase spending significantly.

The OECD is strongly supportive of this approach:

> **"Governments must continue to invest in future sources of growth, such as education, infrastructure and research. Cutting back public investment in support of innovation may provide short-term fiscal relief, but will damage the foundations of long-term growth."**

Research for growth

Universities are a major site of basic research activity in medical, environmental, natural and social sciences alongside research in engineering, arts and humanities. But what contribution does research make to national economic productivity and long-term growth?

The evidence is clear. Research is a key driver of economic growth. It generates growth by supporting innovation and by creating new generations of highly skilled young people working with or educated by leading researchers.

R&D – basic research in particular – lies at the heart of long-term economic growth. It creates what economists call 'positive knowledge spillovers' – benefits to consumers and other companies that cannot be captured by the company or university doing the R&D.

A large body of empirical research in economics shows convincingly that research generates real contributions to innovation and productivity. These operate through several channels.

First, university research increases the productivity of R&D by private companies, as measured by their patenting activity. US research estimates that a 10 per cent increase in university R&D increases corporate patenting by between 1 per cent and 4 per cent (Jaffe, 1989; Jaffe and Trajtenberg, 2002). Since university research is only about one sixth of industry R&D in the United States, this is a positive effect.

Second, because university research raises the productivity of private sector R&D, it encourages companies to do more R&D. This stimulus is also large: the US research estimates that a 10 per cent increase in university research increases private R&D by 7 per cent. This has a further effect on corporate patenting (Jaffe, 1989; Jaffe and Trajtenberg, 2002). The increased R&D and patenting by companies, induced by university research, raises the productivity growth that drives competitiveness and sustainable growth in any economy.

Third, university research has led to the development of many innovations that have been commercialised either through licensing to private companies or the formation of new start-up companies. This 'technology transfer' activity has been particularly intense in the United States since the Bayh-Dole Act in 1980.

This piece of legislation not only gave universities the right to patent new discoveries but also mandated them to license inventions made with federally sponsored research to the private sector. Now, nearly all US research universities have a technology licensing office and explicit intellectual property policies and royalty-sharing arrangements for their scientists.

Between 1991 and 2000, the number of licenses on university inventions in the United States increased from 1,278 to 4,362, and licensing income rose from $186 million to $1.3 billion. Licensing and start-ups based on university innovations are increasing in Europe too, with the UK taking the lead.

Jeremy Watson: Director Global Research for Arup, describes the relationship between publicly funded research and private sector innovation:

> **"Research takes place in both public and private sectors, but company-based research is increasingly outsourced (through offshoring and open innovation), and focused on integration and applications rather than basic knowledge creation."**

> **"There is a strong and growing role for universities to fill the 'basic to applied' gap through fundamental research feeding into the knowledge supply chain. It is unlikely that large companies (with perhaps a few exceptions) will again pick up basic research activity."**

And Rowan Douglas, Chairman of the Willis Research Network, explains the value of research to his industry and to the UK economy:

> **"The sustainability of our industry is crucially dependent on long-term, cutting-edge scientific research. Investment in long-term research is also key to the UK's ability to maintain a competitive global advantage."**

Railways: the industry impact of fundamental knowledge

The importance of basic research for industrial progress is illustrated in this account of academic contributions to the day-to-day running of the UK's railway network. Andrew McNaughton, Chief Engineer of High Speed Two Ltd, outlines his view:

As Chief Engineer of Network Rail, I have supported the Rail Research UK Association (RRUK-A), the partnership between the British Rail Industry and UK universities, since its inception in 2003 and gained first-hand knowledge of RRUK-A research while serving as Chair of the RRUK-A Industrial Advisory Board from 2003 to 2007. Now I am Chief Engineer of High Speed Two Ltd, the company set up by the government to develop high speed rail in Great Britain, I continue to take a keen interest in RRUK-A, as well as the follow-on projects to which it has given rise.

Over the past seven years, RRUK-A has demonstrated the contribution of academic skills, methods and principles in dealing with operational problems faced by those responsible for the day-to-day running of the railway. Key examples include:

- Simple but effective apparatus for monitoring the dynamic displacements of railway track, which in addition to advancing our fundamental understanding of the mechanisms involved has been used to investigate the effects to support stiffness of tunnelling below a railway, the effectiveness of transition zones, and problems associated with ballast movement on high speed railways.
- Understanding of human/machine interaction in railway operations, focussing on signalling and interpretation of CCTV images to detect suspicious behaviour.
- Socio-economic modelling tools to assist with cost/benefit analysis of proposed new stations.
- Novel algorithms for optimising accelerated recovery and minimising train service disruption from unplanned incidents.

With work like this, the myth that academic research and ways of thinking can have little bearing on immediate, real-world issues has been robustly challenged and, in many quarters, dispelled.

Research for skills

University research clearly has an important impact on companies. But it is important to bear in mind that higher education generates two core 'products': research and students. Maintaining a competitive economy in the global market requires both.

Research plays an integral role in higher education by improving the education provided to students and by engaging postgraduate students in the research activity itself. Research also contributes to the reputation of a university and generates additional income by helping to attract international students to work with and learn from world-class researchers. Attracting and retaining high quality staff, which is essential to both of these 'products', requires adequate financial support to provide good research infrastructure and to underwrite frontier research projects.

A recent survey asked UK companies to describe what they most value from the research community (Hughes et al, 2008). The provision of an educated workforce and access to conventional outputs from the research base, such as publications and access to conferences, dominate their responses.

These go alongside an informal process by which potentially mutual interests are identified and satisfied. It is also clear that universities play an important 'public space' role in the provision of neutral ground to facilitate interconnections in the country's system of innovation – not only with the private sector but also with the public sector and the third sector.

Jeremy Watson, Director: Global Research for Arup explains the importance of research-based skills for the UK's economic success:

> "Research is essential to UK Plc as a means of creating capability and hence keeping the country competitive in international markets. A key part of capability creation is the production of a highly skilled research-trained workforce, able to exploit emerging technologies at a world-class level."

> "Increasingly, the rate of production of scientists and engineers in developing economies is placing competitive pressure on the UK's declared differentiator of a 'knowledge economy', and this must be actively defended."

Syngenta: high skills for international competitiveness

Mike Bushell, Principal Scientific Advisor at Syngenta, emphasises the importance of skills for his company's decisions about investment location:

Syngenta is a world-leading agribusiness committed to sustainable agriculture through innovative research and technology. The company is a leader in crop protection, and ranks third in the high-value commercial seeds market.

While we are headquartered in Switzerland, we have a strong UK heritage having operated here for nearly 100 years. We contribute over $1 billion to UK exports and are one of the country's 25 biggest investors in R&D. We spend more than $200 million on the research and development of agricultural technologies in the UK, which represents more than 20 per cent of Syngenta's global spend on R&D.

Syngenta continues to invest approximately 20 per cent of its global R&D spend in the UK because it recognises the key benefit of doing so: the research 'ecosystem' clearly 'punches above its weight' in global league tables by providing a creative academic research system and training its PhDs and post-docs in the skills necessary to solve problems of industrial relevance. The recent investments in university facilities have enhanced prospects of the UK being a leader in key technologies for tomorrow's world.

However, the UK should not be complacent, as many of our developed world and developing world competitors see investment in STEM as the way to stimulate the growth of their economies. Indeed, the UK needs to ensure that it provides an appropriately funded pipeline from primary, through secondary schools and into universities to train the next generation of scientists and engineers, to ensure the UK's continuing international competitiveness.

Public investment in research

The evidence is clear that research has a strong impact on productivity growth. But this does not by itself justify state funding. It is only justified if scientists – or more generally, the universities or companies that employ them – cannot fully capture the social benefits from their research or if, for other reasons such as long timescales, limited capability or high entry costs, there are insufficient incentives to do the research without government support.

For the private sector, there is substantial and consistent evidence of such 'market failures'. For example, companies are generally unable to appropriate the full returns from their research because of 'knowledge spillovers' to rivals and, as a result, they underinvest in R&D (see, for example, Bloom et al, 2010). This is true even in the United States, a country with an impressive track record in innovation and a distinct commitment to the free market.

Since the potential spillovers from research are beneficial to society as a whole – the social returns are bigger than the private returns – there is a strong and clear justification for public investment in research. Such research will benefit the researchers and their organisations but also the much wider economy and society.

For researchers and scientists working in universities and other publicly funded research institutions, they have previously been able to capture at best only a small part of the full social benefit of their research. Until recently one of the few ways for such scientists to appropriate any real monetary gains from their research was through consultancy.

This has changed somewhat with the increase in patenting and licensing activity by universities over the last 20 years. But while there are a few publicised cases of scientists doing very well from their inventions, these constitute a tiny fraction of scientists. What is more, although research shows the significance of incentives for innovation and licensing in universities, royalty sharing gives only a fraction of the gains to the university scientist or researcher (Lach and Schankerman, 2008)

Studies show that scientists prefer to work in more open research environments, where freedom to publish is greater (Dasgupta and David, 1994; Belenzon and Schankerman, 2008). Researchers typically pay for this preference in the form of lower salaries than they would earn in more closed research environments. This applies both to companies with such policies and, especially, to universities whose defining characteristic is the freedom to choose research projects and publish results.

But while some scientists and researchers are willing to pay something for the flexibility of a more open research environment, they are not willing to pay any price. Sufficient retrenchment of government support for research will induce scientists to leave the university to conduct their research elsewhere in the world.

The House of Lords Science and Technology Committee has recently expressed concerns about the threat to UK research skills:

> **"Any cuts in funding for science research in the forthcoming comprehensive spending review risk making the UK uncompetitive in attracting the top science researchers and could undermine the UK's reputation as a centre for high standards of scientific research."**

The Committee wrote to the vice-chancellors of six leading research universities asking about their experiences recruiting and retaining high quality science research staff. Based on the responses, the Committee say that talent in scientific research is highly mobile with 23 per cent of academic staff working in the UK being non-UK nationals. They argue that there is 'significant risk' the UK will lose out in a 'global talent war'.

For example, Professor Andrew Hamilton, vice chancellor of the University of Oxford, says:

> **"We have very real concerns that the brightest and best researchers at all stages of their career could accept offers of study or employment at our international competitor institutions should the national funding environment become more challenging."**

The continued need for public investment in UK research

The need for public investment in research is clear, but is it important for a country like the UK to maintain its own science base? Could the UK 'free-ride' on the university research of larger countries, notably the United States?

First, free-riding 'works' only if it can be done without significantly reducing the available pool of research. This requires that the free-rider is a small contributor relative to the total, and that punitive reactions can be avoided.

But the UK is not a small player in global science and research. Indeed, the country ranks high in terms of publications per head of population – about 50 per cent higher than the EU average and 16 per cent higher than the United States. Any serious cutback in the UK would have a significant effect on the pool. It might also trigger attempts by other countries to restrict UK scientists' access to research findings.

The second, and more important, reason why free-riding is not a practical option is due to what economists call 'absorptive capacity'. Researchers cannot effectively exploit the cutting-edge research of others unless they are themselves active in research. A strategy that relies on importing ideas may work, but it cannot be the source of long-term productivity growth.

While in theory companies can take advantage of innovations discovered overseas, in practice higher R&D spending has been shown to help companies adopt foreign innovations more easily (Griffith et al, 2004). UK companies also benefit from conducting R&D abroad (Griffith et al, 2006).

This body of research describes the 'dual aspects' of R&D: its value not just in pushing forward the technological frontier in itself, but also making it possible for companies to learn about and absorb innovations from elsewhere, including the output of basic research. There is solid evidence across a broad range of industries that countries can speed up the rate at which they catch-up with the productivity frontier if they have a stronger R&D base.

In a recent speech, universities and science minister David Willetts acknowledged the significance of this research evidence:

> "I think that the answer is that we need enough good science so we have the capacity to tackle a new problem, to react effectively to scientific breakthroughs however or wherever they may arise, and to capitalise on those breakthroughs via research programmes and business initiatives of our own."

> "Some 95 per cent of scientific research is conducted outside the UK. We need to be able to apply it here – and, in advanced scientific fields, it is often necessary to conduct leading-edge research in order to understand, assimilate and exploit the leading-edge research of others."

> "It is this absorptive capacity which is crucial. Indeed, Griffiths, Redding and Van Reenen [Griffith et al, 2004] have shown that higher domestic business R&D spend also leads to greater productivity being generated at home from foreign R&D spend as well. And there are powerful feedback mechanisms on top of this – foreign companies cite the quality of the public research base as one of the main reasons for locating their own internationally mobile R&D here."

Asim Gaba, Director at Arup, lays out his personal opinion on the choice for the UK in its approach to research:

> "The key question for UK Plc is whether it wants to remain at the forefront of technological advancement or whether it chooses to become a consumer of technology developed by others – effectively a choice between leadership or following. The former is where the UK is and has been historically. At Arup, this issue is beyond debate – we are very much in the former of the above two categories."

Research for local development

What impact does a university's research have on the innovative activity of firms that are located close to the university? Understanding whether knowledge transfer is geographically localised is essential to understanding whether it matters if research happens at home or overseas – and whether research should be spread across regions or whether individual clusters of excellence are more conducive to university-industry knowledge transfer.

A recent study analyses the relationship between the number of patenting manufacturing firms and the quantity and quality of relevant university research across UK postcode areas (Helmers and Rogers, 2010). It finds that different measures of research 'power' and 'quality' positively affect the patenting of small firms within the same postcode area. This indicates that small firms benefit from localised university-industry knowledge transfer.

Patenting by large firms, in contrast, is unaffected by research undertaken in nearby universities. This confirms the commonly held view that location matters more for small firms than large firms. However large firms are still not benefitting from university research. As indicated by studies described in the next section, many multinational firms choose to locate their R&D facilities close to relevant centres of academic research.

A further study of research and local development examines the impact of university business incubators on innovation by firms close by (Helmers, 2010). Standard business incubators provide start-up companies with a range of support measures, including physical space within the incubator building, training and coaching, business contacts, access to finance, etc.

University incubators have the additional advantage that they can draw on the resources available at the university, including academic support, access to research facilities, as well as easy access to the student pool to recruit employees.

The study finds that the recent wave of establishment of new university business incubators in the UK has generated local externalities by increasing the patenting propensity of incumbent firms located geographically close to the new university business incubators. Incumbent firms react to the entry of new firms within the same sector by increasing their propensity to patent by 2-6 per cent.

The effect is stronger the closer the entrant is geographically located to an incumbent – the strongest impact occurs within a radius of 5-15 kilometres. Beyond 100 kilometres, entry has no economically significant effect on incumbent patenting.

Recent research on knowledge spillovers from university innovation in the United States confirms that, for companies to use publicly funded research most effectively, geographical location has a significant contribution. (Belenzon and Schankerman, 2010.)

Analysing patent citations both to university patents and scientific publications, the study finds that knowledge spillovers are strongly localised, sensitive to distances of up to 15 miles. Companies located in the same state as the cited university are substantially more likely to cite one of the university patents than a company located outside the state.

Inward investment by foreign companies

Sustaining the UK's research base will also sustain the attractiveness of the UK as a location for inward investment by foreign companies. The current high quality of UK research makes the UK attractive for investment by international business and industry through collaborations and siting offices here.

Indeed, the UK attracts a higher share of its R&D from overseas than any other country in the G8. Multinationals and foreign companies carry out a large share of R&D in the UK. Foreign multinationals perform more than 40 per cent of R&D in the UK, with US multinationals alone accounting for 25 per cent of the total.

Stephen Bold, Managing Director of Sharp Laboratories of Europe, explains why the UK is an attractive location:

> **"Clearly it is the excellence of the UK science and engineering base that encourages foreign-owned firms to invest in R&D in the UK."**

There is evidence that private sector R&D labs in the UK are disproportionately clustered around highly rated university research departments (Abramovsky et al, 2007). This phenomenon is not driven just by university 'spin-outs': in some industries, foreign-owned companies are choosing to locate in close proximity to high quality research. This implies that multinational companies may be sourcing cutting-edge technologies from universities in the UK.

The results of this study show that R&D facilities 'cluster' near university departments, particularly in the pharmaceuticals and chemicals sectors. A postcode area (for example, 'OX' for Oxford) with a chemistry department rated 5 or 5* by the 2001 RAE is likely to have around twice as many labs doing R&D in pharmaceuticals and around three times as many foreign-owned pharmaceuticals R&D labs compared with a postcode area with no 5 or 5* rated chemistry departments.

Examples of the value of such clusters are the UK's two National Science and Innovation Campuses, Harwell and Daresbury. After only two years, the latter had secured £70 million of investment, created 90 high value new jobs and attracted 85 high-tech small and medium-sized enterprises producing sales valuing £15 million.

Research also finds evidence that foreign-owned labs in the machinery and aerospace sectors are likely to be located near to materials science and electrical engineering departments rated 4 or below by the RAE (Abramovsky and Simpson, 2008). This suggests that companies also benefit from proximity to more applied, commercially oriented research activity.

Steve Battersby, Senior Director Innovation at Philips Research Laboratories in Cambridge, underlines the importance of the science base for business success and national prosperity:

> **"Having a strong research community in the UK is important for growth and prosperity. Investors, whether large companies or VCs, tend, where all else is equal, to put their investment for a new business opportunity with, or close to, the team that originally created that opportunity. So the location of high-tech manufacturing, sales, technical support, services can all be located in the UK if the original opportunity was created here."**

> **"We must maintain the academic quality of our top universities on a global scale. In our case at least, our academic partners are typically drawn from the top 10 universities in a given country. To compete globally based on a know-how economy, we must also compare favourably in our top universities."**

Sharp Laboratories of Europe: a view on how UK research attracts inward investment

Stephen Bold, Managing Director of Sharp Laboratories of Europe, explains why the UK is an attractive location for inward investment in R&D:

We are a research laboratory of 100 researchers based in Oxford. We are wholly owned by Sharp Corporation of Japan and attract inward investment to the UK of approximately £14 million every year. We are part of the research activity in the UK funded from abroad. Overseas funded R&D in the UK is nearly as large in size as the government programme.

Our view of the UK science base

Clearly it is the excellence of the UK science and engineering base that encourages foreign-owned firms to invest in R&D in the UK. However the argument should not be generalised: it is strength in particular sectors that attracts particular companies. A key reason for Sharp to establish R&D in the UK was the strength of liquid crystal expertise in UK government laboratories.

Key collaborations

Sharp Laboratories has enjoyed many key collaborations over its 20-year history in the UK. A collaboration with Professor Colin Humphreys on LED would be an excellent example and a key reason why Sharp chooses to carry out research on MBE growth of LED here in the UK.

Important benefits of research to industry

Although Sharp Laboratories has enjoyed close collaboration with many universities, resulting in significant technology transfer, by far the biggest benefit we receive is a supply of excellent researchers. Our income is in direct proportion to the number of researchers working here. Over the last 10 years we have more than doubled the annual inward investment from Japan to the laboratory and that depends completely on recruiting excellent researchers.

Creating the conditions for business, industry and research collaboration

Researchers everywhere are greatly influenced by the metrics of funding. At this laboratory our success is measured by value added through transfer of technology into mass production. The same metrics determine our funding. In academe there are many metrics that determine access to funds and in order to promote collaboration with business and industry it is essential that funding metrics reward it.

Measuring the impact of publicly funded UK research on growth

How much does the knowledge from university research in the UK affect growth in the private sector? A recent study has measured the impact of public investments in research and finds strong evidence of very high productivity benefits for the rest of the economy (Haskel and Wallis, 2010). These benefits arise from Research Council spending rather than from research that is directly government funded or from tax incentives for private sector innovation.

Measuring the effect of public sector knowledge on private sector growth is difficult because it is essential to control all the other factors that might affect private sector growth. The most obvious ones are companies' accumulation of their own knowledge, via investment in R&D, software, etc., plus the accumulation of other inputs, such as hiring more labour and employing more machines.

Thus the starting point is to try to measure that part of growth not accounted for by companies' own investment in knowledge, capital and labour. This is what economists call total factor productivity growth. Single factor productivity is output per unit of labour input; total factor productivity is output per unit of labour, capital and own-knowledge input.

Total factor productivity growth is then that part of private sector growth determined by factors not directly funded by the private sector. So it could be determined by publicly funded knowledge from UK universities that is free to everyone. Or it could be determined by knowledge freely available from anywhere in the world, be it publicly funded by other countries or privately funded, but leaking out of the private sector in those countries. The medium of such knowledge spillovers could be the internet, foreign trade or foreign direct investment.

Attempting to parse out these possible effects is what the Haskel and Wallis study tries to do. In Figure 1, the vertical axis shows total factor productivity growth (TFPG). In 1987, for example, the upper left point, this was 2.5 per cent (each point is a year). The horizontal axis is spending on Research Councils in the previous year (as a proportion of GDP).

Figure 1 shows the line of best fit and is upward-sloping in a statistically significant positive relationship. Increases in public support for R&D via the Research Councils are associated with increases in private sector productivity growth a year later. A very similar picture holds for lags of two and three years.

The study finds no evidence of such spillovers to the private sector from public spending on civil or defence R&D nor from companies' own investment in intangible assets, including R&D. Taken together these findings tentatively suggest that in a world of constrained government spending, public policy for innovation should focus on direct spending on innovation, specifically the Research Councils, rather than through tax incentives, such as the R&D tax credit, to companies.

Haskel and Wallis use the slope of the line to determine the contribution of spending by the Research Councils to GDP. With current annual spending at around £3.5 billion, the slope suggests that this gives around £60 billion additional market sector output. Halving this for a more conservative estimate gives a contribution of publicly funded research to GDP of £30 billion, which is about 2 per cent of GDP. Put another way, if support for Research Councils were cut by, say £1 billion from its current £3.5 billion, GDP would fall by around £10 billion.

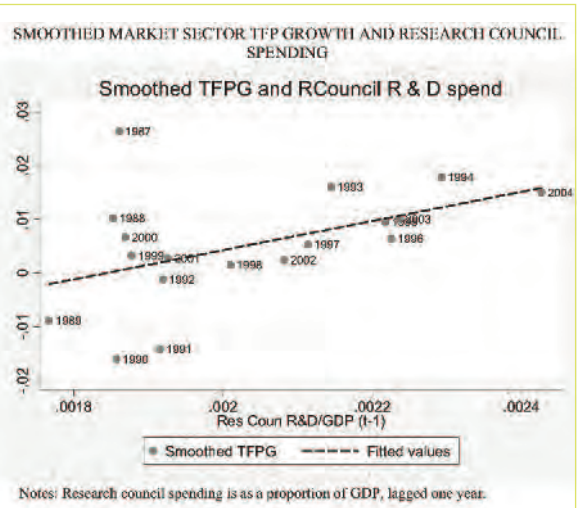

Figure 1: Impact of Research Council spending on productivity

What about government funded research and the Research Councils' public sector collaborations more broadly? For example, what would happen to the research base if the defence budget were to be cut?

At least 15 government departments have close working relationships with the Research Councils, putting the latter in the ideal position to help drive efficiencies within public services. But as cuts fall across government, it is important to ensure that cuts to departmental research budgets do not affect the Research Councils' ability to invest in particular areas, for example through the Office of Civil Society or Department for Transport where there are already joint investments.

There is real potential for increased efficiency savings around data collection and surveys: closer collaboration and co-funding through initiatives such as the National Data Strategy for Social Sciences, and collaborative funding for large scale longitudinal studies such as Understanding Society and the Birth Cohort Facility which can help provide evidence for policy.

Collaboration between universities and industry

It is sometimes said that university researchers remain too isolated from the outside world and that recent income gains from contract research, collaborative research and training as well as continuous professional development would be much larger but for cultural factors that inhibit their growth. A survey of over 20,000 individual academics across all subjects and all universities in the UK shows that this view is quite wrong (Hughes et al, 2008).

The survey asked the academics to classify their activity into basic research, user-inspired basic research and applied research. Nearly 70 per cent described themselves as doing user-inspired and applied research. Basic research is relatively more important in physics, biology and the arts and humanities, but here too there is a wide range of the applied and user-inspired research interactions that dominate engineering, health and the social sciences.

A parallel survey asked companies about the main impediments to their effective interaction with universities. Rather than talking about differences in cultures or time frames, they typically cited their own internal capacity to access and manage these interactions effectively. It is also clear that the private sector values access to universities for inputs across the value chain, encompassing the social sciences, arts and humanities and not just technology inputs from the natural sciences (Hughes et al, 2008).

Another study looks at the impact of universities and other higher education institutions on the innovativeness and competitiveness of three specific regions – Wales, the north west and the east of England (Howells and Huggins, 2010). Analysis of data drawn from more than 370 firms and 18 universities shows that collaborations between firms and universities have a 'positive and significant' effect on firm innovation.

Although universities may not be the initial favoured collaborators for firms, there is a significant and appreciable influence on innovative performance when such collaboration does occur. Firms with university collaboration are four times more likely to innovate than those without, including organisational innovation. Both formal and informal university collaborations (such as conferences, meetings and workshops) were equally important to innovation outcomes.

Mining and research: a novel form of research-industry interaction

Dr Jim McQuaid, Chairman of the Deep Underground Laboratory Steering Group, describes an unusual example of research-industry interaction, which might be a model for wider adoption where similar circumstances apply:

Cleveland Potash Limited (CPL) operates a potash and rock salt mine at depths down to around 1100m under the North Sea at Boulby near Whitby. The depth of the mine ensures a low-background radiation environment particularly favourable for research in particle physics and nuclear astrophysics.

For the past 20 years, CPL has provided free access to extensive underground space for a well-equipped laboratory for researching the above topics. The research scientists are able, at marginal cost, to use the essential supporting facilities of the mine, for example, electricity supplies, ventilation, shaft transport for personnel and equipment and so on.

Direct support for curiosity-driven, or 'pure', research seems to be rarely, if ever, offered by industry. Such research, by conventional definition, has no perceived connection, now or in the medium term, with industry's needs for business-relevant information or ideas. The stance of industry is quite understandable; support for curiosity-driven research is generally regarded as being in the province of government or charitable foundations.

But this example suggests that the act of supporting curiosity-driven research can add value to the supporting business independently of the actual research undertaken. CPL has, in effect, identified a particular kind of value for their business from their interaction with pure science. The conventional separation of 'pure' and 'applied' research hardly applies. The research is 'pure' in the eyes of the scientists but for CPL it is 'applied' in the sense that the act of supporting it helps to fulfil a desirable business objective independently of the nature of the research.

The interaction is believed to be unique in its structure, going beyond existing frameworks and focusing on curiosity-driven research. The example shows that different forms of value can be created for both sides and for the wider UK economy.

RESEARCH IMPACT

The positive impact of research on UK business, the economy and society as a whole can be measured in many different ways. The following is a small sample from the different Research Councils of what has been achieved over the past couple of decades. Many more case studies are available from the individual Research Councils and on the Research Councils UK 'framework for the future' website (www.rcuk.ac.uk/framework).

Plastic electronics

Plastic Logic, a spin-out firm from Cambridge University, raised £50.6 million in venture capital to build the first ever plastic electronics manufacturing plant to produce its 'take anywhere, read anywhere' electronic readers. These portable readers will make the experience of reading from an electronic device far more like using paper than any previous technology, solving the strain of reading text from laptops. By printing on thin and flexible plastic substrates, this technology has the potential to reduce significantly the cost of consumer electronics and reduce the impact of printing to paper.

Founded in 2000 by Professor Sir Richard Friend and Professor Henning Sirringhaus, Plastic Logic is now a leader in the field of plastic electronics manufacturing. Sir Richard says: 'This development comes on the back of a long-term programme of basic science supported by the EPSRC (Engineering and Physical Sciences Research Council). It is this support that has enabled us to stay at the top internationally.'

Basic research in polymer science funded by EPSRC has led to direct and indirect impacts amounting to around £200 million. UK research has played a significant role in developing and exploiting polymer technology for display applications.

Energy spin outs

Ceres power was formed in 2001 after 10 years of Research Council funded research on materials and devices, and is now an AIM (Alternative Investment Market) listed company employing 70 staff, working with British Gas to develop a fuel cell microchip product for the UK market. The company enjoys the support of many blue chip City institutions as financial backers, including Fidelity, Morley and JP Morgan.

Ceres Power acquired fuel cell intellectual property rights developed by Imperial College and went on to develop practical, mass manufacturable fuel cells designed to work with a range of fuels including natural gas, methanol, hydrogen and vehicle fuels. Ceres is now integrating the technology into complete systems and products, for applications such as domestic combined heat and power, vehicle auxiliary power units and efficient off-grid power generation.

Flooding

Flooding caused by tidal surges is a serious threat to the people and businesses of London. The erection of the Thames barrier is a great engineering feat to counter this threat. The technology would be ineffective without NERC (Natural Environment Research Council) tidal data from scientists at the Proudman Oceanography Laboratory (POL) and prediction capabilities that inform decisions on when to raise or lower the gates.

POL is sited in a £5 million, purpose-built site on the University of Liverpool campus. Scientists at POL research and monitor storm surges responsible for flooding, global sea level rises, oil spill movements and how pollutants disperse. The laboratory gathers the data that regulates the operation of the Thames Barrier that protects London from flooding. The cost of getting this wrong and London flooding could be as much as £30 billion, without counting the loss of human lives.

Solving strategic issues

Sometimes companies need to deal with major strategic issues and social science can help here. Airlines, including low-fares carriers such as Flybe, easyJet and Ryanair, have come under a lot of external pressure in recent years for their alleged negative environmental impact. For some airlines, the fear of negative public perception of their corporate social responsibility (CSR) communications has been one of the main reasons they have been reluctant to fully report all of their socially responsible activities, according to ESRC (Economic and Social Research Council) research by the Centre for Sport, Leisure and Tourism Research at the University of Exeter Business School.

Adopting a CSR strategy requires the airline to consider finance, resourcing, time, staffing, PR, communications, positioning strategies and partnership relationships. "Access to independent and high-quality research into an important issue facing airlines is crucial," says Niall Duffy, Head of PR and Public Affairs at Flybe. "The study has helped us identify and overcome challenges in rolling out our CSR and gives us greater clarity in our environmental record and community involvement."

Spectrum auctions

Outcomes are sometimes less visible than in the natural sciences, but the contributions of economic and social research can also have large payoffs. One example is auction theory, a branch of the theory of games, which played a key role in the design of the auctions for radio spectrum that were adopted first by the US Federal Communications Commission (FCC), and subsequently in Europe and elsewhere.

In 1994-98, the FCC auctioned off radio spectrum that had previously been given away for free, bringing in revenues to the government of $22.9 billion and ensuring that use of the spectrum was now allocated to the most productive users. The UK's spectrum auction in 2000 generated £22.5 billion – and two ESRC funded game theorists – Professors Ken Binmore and Paul Klemperer – played key roles in its design.

Stem cells

UK researchers discovered how to culture embryonic stem cells. Continuing support for stem cell research has placed the UK in a leading position in regenerative medicine, an industry that is currently worth more than £500 million per annum, and estimated to rise to around £1 billion by 2013.

Creative industries

The impact of research in the arts and humanities is often less visible. But it plays a vital role in important emerging sectors, such as the creative, digital and information technology industries, which have the potential to generate high economic benefits.

Recent data suggest that the creative industries in the UK have the potential to grow on average by 4 per cent over the next five years (more than double the likely rate of the rest of the economy), generating £85 billion in gross value added (up from £59 billion). By 2013, the sector is expected to employ 1.3 million people.

VOICES OF BUSINESS

There are numerous examples of businesses confirming the value of public research in their everyday work. The following three case studies give an indication of some of the big successes in collaboration between research and business, as well as key conditions that need to be nurtured to create an environment where such interactions can flourish.

Philips Research Laboratories: a perspective on big successes in research, innovation and commercial application

Steve Battersby, Senior Director Innovation at Philips Research Laboratories in Cambridge describes three examples and draws out the lessons for effective collaboration between university researchers and the private sector:

Business and industry successes

A business success comes about when an innovation matches a market need. Philips seeks to build its business by providing solutions to societal and individual issues such as the aging population, environmental impact, personal health and well-being and access to healthcare. In our approach to innovation, we seek insights which identify specific market needs and then seek innovative solutions. Often, the solutions come from building on the work of academic partners, work often initiated through curiosity-driven research.

For Philips, an example of a 'big success' would be the invention of the CD, the digital audio format introduced in the 1980s, which swept away the black vinyl disc and the compact cassette (also a Philips invention). Here, the need was for a high quality audio media, worthy of the emerging digital revolution, in a format convenient and compact. Almost every aspect was revolutionary, including the use of the 'pit' structure on the CD as the digital store, the use of the laser as the read-out system (the first mass-market application of what was, at that time, an esoteric scientific curiosity), the replication technique and the error correcting coding system.

My second example of an industry success is the active matrix LCD, now the dominant display technology having driven the CRT almost out of existence. The need for such a display arose as a result of simultaneous developments in microprocessor chips and memory, both disk drives and RAM, which enabled true portable computing in the form of the laptop PC. Often cited is the role of Hull University and BDH, Poole (now Merck) in the development of the LC materials themselves. Less recognised is the role of Dundee University, where Spear and LeComber developed the first hydrogenated a-Si transistor, now the mainstay of the industry for the pixel switch.

The industry, however, was created by the collective ambition of many companies in the supply chain, creating solutions for the LC materials, the manufacturing equipment, the glass substrate, colour filter materials, the backlight systems and more. The resulting industry is, of course, largely Asian as this is where the centre of gravity of this collective ambition was based, showing that, even though the inventions may have been made in the UK, this was not sufficient to defend an industry where pure manufacturing strength, rather than IP and know-how, was the dominant control point.

My third example, from a very different discipline, would be Solexa, a Cambridge start-up set up to develop a next-generation DNA sequencing engine based on ideas from Shankar Balasubramanian and David Klenerman of the University of Cambridge Chemistry Department. Sold to Illumina for $600M, this technology is now used in approximately 90 per cent of the new orders for sequencing systems in North America. In this case, the need remains unproven, but is based on the assumption that low cost DNA sequencing will revolutionise the treatment of disease and health, enabling a personalised approach based on genetic data.

Key drivers of successful collaboration between researchers and business

Although drawn from very different businesses, these successes have a number of common factors:

- They all started with top quality scientists exploring a challenge at a fundamental level, maybe without a clear application in mind.
- At a later stage, an emerging market need was identified where the innovative step was to match the need to the most suitable enabling technology.
- Turning that into a big success then relied on an excellent scientific team with a shared vision, a culture seeking excellent solutions together with investment to enable progress.

Of course, my first example is a success for Europe, the second for Asia and the third for the UK.

Requirements for future effective collaboration

There are several pre-requisites that can be identified for collaborations between researchers based in universities and business, including:

- The existence of an academic pool of wisdom, typically gained through exploratory research work.
- An identified need which represents an opportunity for business.
- Principal investigators (PIs) doing the curiosity driven research who seek applications where possible or who are supportive of others who seek applications for their work.
- A process whereby it is possible to connect the achievements of the academic research to the identified need. This is perhaps the biggest challenge in generating big successes. Improving this process has the potential to generate more big successes.
- A team with the ambition and skills required to make progress towards the identified goal. Ideally, this team should include the PI but, if not, the PI should strongly support the team.
- Organisations (VC investor, a corporate, government or seed funding) who recognise the need, can evaluate its business potential as attractive, see the team as having the right abilities and have the funds to allow that team sufficient freedom to work towards its goal.

Arup: the UK must choose to remain at the forefront of technological advancement

Asim Gaba, Director at Arup, lays out his personal opinion on the choice for the UK in its approach to research:

The value of research to business and industry is, of course, critically important. To state the obvious, academic research creates new knowledge/perspectives/understanding, which in turn leads to innovation and creative design and to new products/services, etc.

The key question for UK Plc is whether it wants to remain at the forefront of technological advancement or whether it chooses to become a consumer of technology developed by others – effectively a choice between leadership or following. The former is where the UK is and has been historically. This has simply been the result of successful practical application of research to meet business and industry requirements through collaboration for mutual benefit.

At Arup, this issue is beyond debate – we are very much in the former of the above two categories. Research is a key contributor to Arup's success: we deliver new validated thinking in support of our clients' projects and aspirations and maximise value by matching business requirements with developments from the academic sector.

Research has always differentiated Arup's work and will continue to do so – we encourage it globally. Arup experts work in collaboration with the best private and public sector clients. An internal research investment fund supports staff time and provides studentships and other contributions to university collaborators. Many Arup staff members are renowned in their fields, publishing in peer-reviewed journals.

While we have much expertise in-house, we continually strengthen, supplement and enhance this through strategic alliances and partnerships with individual universities and academic institutions aligning our thinking with national research priorities.

Links with the UK Research Councils are also very important, for example, we have a strategic partnership agreement with the EPSRC, which supports mutually developed research programmes between Arup and individual universities and academic institutions.

Such partnerships and research initiatives are exciting, innovative and great to be involved with. As well as allowing us to grow knowledge and demonstrate excellence in many technical areas, they ensure that we develop relationships with the best in industry and academia to provide research that significantly adds value to our clients.

The benefits of such collaborative efforts are obvious – apart from a valuable source of recruiting/retaining staff knowledgeable in the areas of new skills/knowledge crucial to our future business needs, this keeps us at the forefront of leading edge technology from which we can develop new services and innovative solutions and hence new business opportunities going forward.

Another area of obvious benefit is to integrate research findings into good practice guidance documentation for the benefit of industry practitioners as a whole, such as CIRIA reports and this is where associations between Arup and academia yield real dividends. For example, collaboration with the University of Southampton has featured prominently in recent years – most notably on CIRIA C517 (Temporary propping of deep excavations – guidance on design) and C580 (Embedded retaining walls – guidance for economic design).

These are, of course, big success stories as are project specific collaborations with Arup, such as on the Channel Tunnel Rail Link and, most recently, jointly bidding for the forthcoming sand dunes migration/mitigation research, modelling, analyses and studies for the Union Rail project in the United Arab Emirates.

The key lesson to ensure that research continues to play a prominent role in promoting future growth and prosperity of UK businesses and industry is obviously closer collaboration between academic institutions/research bodies and industry in a much more interactive manner than at present, with meaningful representation from both sides on academic and professional bodies to align and further mutual interests and benefit.

Willis Research Network: why investment in long-term research is key to the UK's ability to maintain a competitive global advantage

Rowan Douglas, Chairman of Willis Research Network:

Willis is an international insurance and reinsurance broker headquartered in London with 20,000 staff worldwide. The company assists public and private sector institutions identify, evaluate and manage risk and arranges insurance, reinsurance and related transactions to reduce exposures to tolerable limits.

In recent years the company has made significant investments in public science via the Willis Research Network (WRN) to confront challenges of evaluating the financial impact of extreme events, natural catastrophe and man made risks. The WRN funds posts at around 40 universities world-wide and also supports non-university public science bodies. Almost half of these institutions are in the UK.

The UK is a major world centre of climate modelling. Its remarkable concentration of modelling activities across the full spectrum of climate, environmental, engineering, medical, economic, financial and social domain in academic and external sectors makes it one enormous 200 mile radius cluster. The role of improved communications is enabling UK based science to lie at the heart of model-based decision-making – globally.

A simple case study is from non-life insurance, an integrated $2 trillion global market. Around the world, regulators are adopting an emerging standard, led by the EU, which dictates that insurance contracts should tolerate the 1 in 200 year loss extremes. The result is that insurance companies must have access to sufficient capital to cope with the 1 in 200 year worst case scenarios, from natural catastrophes to financial crashes. However, history alone provides an insufficient guide to evaluate these risks it requires simulated modelling of current exposures.

For example, there is now a direct supply chain emerging that incorporates basic climate science modelling, risk capital modelling, and regulatory modelling. The financial impact of such science, mediated via models, on insurers is significant. Most decisions and transactions in the sector are now undertaken in the modelled world. The most successful companies are those who are its master rather than its servant.

The integration of UK public science, together with its funding agencies and commercial sector, has rendered it at the heart of global risk modelling. In future years UK-based data, methods, expertise and tools are set to lay at the core of risk decision-making and responses from Chinese climate to Chilean credit risk.

The sustainability of our industry is crucially dependent on long-term, cutting-edge scientific research. Investment in long-term research is also key to the UK's ability to maintain a competitive global advantage. If the UK and British industry are to prosper and grow, we must do more than simply keep up with our competitors, we must get ahead of them.

Getting ahead means stimulating innovation, which crucially hinges upon research. Economic competitiveness will not improve through research-led advancement unless industry seizes the opportunity, and increases its ability to draw on the expertise of academics around the world.

To ensure research plays a pivotal role in the future growth and prosperity of the UK, we must provide effective incentives for businesses to develop research programmes and strengthen the pipeline of support between business and academia; put in place measures to enhance skills in business research and development; and encourage business to recognise the value of investment in research.

Creative industries: opportunities for new businesses

The UK has an historic opportunity to be a global leader in creative, digital and information technology (CDIT) industries, according to a recent report (CIHE, 2010). The Fuse calls on the government and its agencies to acknowledge CDIT as a strategic priority and to discourage transactional business-university relationships that place a heavy emphasis on patents and spin-outs rather than nurturing start-ups.

Universities and funding bodies are urged to find better ways of working with graduate-rich small and medium-sized businesses in the CDIT industries and to prioritise technology-heavy CDIT programmes. By taking a more interdisciplinary approach and working more closely with business, universities can provide high-quality graduates with a range of work skills and the flexibility and knowledge to remain innovative throughout their careers.

The report also calls on business to play its part in developing graduates capable of leading the UK's CDIT industries. It calls on employers to collaborate closely with the universities that supply them. It also proposes that industry bodies should promote volunteer schemes through which professionals can work with students and help them develop the employability skills they need for the CDIT jobs market.

Farm businesses: research for new products, technologies and management practices

The NFU represents 55,000 farm businesses in England and Wales involving an estimated 155,000 farmers, managers and partners in the business, plus 55,000 'Countryside' members with an interest in farming and rural issues. The NFU's key concerns are as follows:

It is vital that scientists with the motivation and skills needed to take discoveries through to application are recognised and rewarded in the same way as those doing fundamental research. It also needs to facilitate the close relationship between groups of scientists and/or whole institutes and the industry sectors their research is relevant to, such that business can readily identify them as centres of excellence and genuine knowledge exchange is achieved.

If this is effective, their research will be driven by the challenges faced by farming in the 21st century, that is, being more efficient, productive and resilient, at the same time as delivering public goods and reducing impact on the environment, in the context of climate change pressures. This should be as true for basic research as for applied, just that the timescales are different. The way agricultural businesses are linked in to the land grant colleges and research centres in the US seems to be a valuable model of this.

The NFU strongly believes that for bioscience to have value for farmers there must be effective and well-resourced mechanisms and facilities for knowledge exchange. Research results must eventually be commercially practical, whether through products, technologies or management practices.

Building skills and understanding changing consumer behaviour

Social science can benefit business in numerous ways: from helping to set a business strategy to enhancing business operations.

Some of Britain's biggest brands, from Royal Mail to travel company Thomson, used leading-edge social science research to better understand how changing consumer attitudes to climate change may affect their businesses.

Royal Mail gained insights into consumers' willingness to pay to recycle items such as batteries through the post, while Thomson discovered that travellers would respond positively to initiatives to help lower their carbon footprint.

The findings were made possible through research collaboration between a consultancy firm – Future Foundation – and the ESRC Centre for Business Relationships, Accountability, Sustainability and Society at Cardiff University.

On an operations level, social science has enhanced the project management skills of over 450 business practitioners. In Birmingham, social science research helped businesses with strategy implementation through effective project management. The Centre for Project Management Practice at Aston University brought together project management practitioners and researchers. In two years, the centre has helped 450 contacts in over 170 businesses and organisations improve their project management skills and techniques through seminars, mini-exchange placements and social science research.

Entrepreneurial academics

So are there real barriers to successful collaboration between universities and business that need to be tackled? A recent study by the Advanced Institute of Management Research suggests that far from being cut off from society in the ivory towers of popular imagination, UK researchers are highly entrepreneurial (Salter et al, 2010). Furthermore, the last five years have seen academics and industry forge ever closer connections.

UK academics are competitive with their international counterparts in terms of their links with business and industry. These links are often fundamental to how they conduct their research.

But this is not the perception of UK policy-makers, who continue to urge academics to greater engagement as if little of it exists and who consequently fail to support the mechanisms for engagement that matter. According to the study, the false assumptions about the nature of academic entrepreneurship have arisen because of the way engagement is currently measured.

Over the past 10 years, the focus has been on counting university start-ups, patents and licenses when, in fact, the vast majority of the interactions between academics and industry have little to do with formal intellectual property or venture creation. Indeed, many engagements are small-scale and informal.

They include projects such as the creation of new facilities with industry funding, the training of company employees or postgraduate training with a company, joint research, consultancies and the attendance of academics at industry-sponsored meetings. Such forms of collaboration are missing in the statistics of formal engagement.

The real issue, the researchers argue, is not that our intellectuals are remote from practice but that their collaborative and entrepreneurial efforts have effective support from universities and government.

Through Pathways to Impact, the section on the research proposal where applicants outline the types of activities that they will engage with to reach potential beneficiaries, RCUK is leading the sector by providing crucial support for these activities from the outset of the research.

The study validates the RCUK policy of supporting the whole spectrum of engagement mechanisms used by academics and industry to deepen ties.

The study also suggests that entrepreneurial efforts of individual academics should be better valued. Although entrepreneurial activities are seen as being useful for research, they are perceived to be of little or no value by departments and universities in their hiring and promotion policies.

Furthermore, although there are differences between disciplines, external factors rather than simply individual characteristics drive the rate and direction of academic entrepreneurship. This suggests that policy measures need to create more opportunities for academics working in fields with little entrepreneurial opportunities, or where such opportunities are more remote from the market.

Dr Ammon Salter, who led the research, concludes:

> **“Creating more time, resources and support for academics to engage in venture creation, especially in disciplines where such activities are uncommon, may yield the greatest return to policy efforts. Indeed, if government and universities believe entrepreneurial efforts to be important they should give them more clear support, training and profile.”**

Keeping UK public investment in research on track

This report began with three questions:

- What contribution does scientific research make to innovation, productivity and long-run economic growth?
- Why does such a substantial share of a country's spending on R&D need to be publicly funded, even in the United States?
- And is it really necessary for the UK to sustain the current level of public investment in research, particularly in straitened economic times – or can UK businesses and the UK economy 'free-ride' on research done elsewhere?

The answer to the first question is straightforward. Virtually all evidence indicates that the new knowledge and innovative ideas generated by research (whether done in the public or private sector) are key drivers of productivity growth. And as the economics Nobel laureate Professor Paul Krugman once wrote, 'Productivity isn't everything – but in the long run, it's almost everything'.

Answering the second and third questions is more complex. To understand why public spending makes up a substantial proportion of total spending on research, it is essential to understand the idea of 'market failure' – a situation where, for various reasons, the private sector fails to deliver products and services that would benefit society.

In this case, the potentially high costs of research in terms of both money and time and the very uncertain payoffs discourage firms from spending as much on R&D as they otherwise might. They are further discouraged by their inability to reap all the benefits of research because of 'knowledge spillovers' to other firms. As a result, without public investment, society as a whole would underinvest in research.

Public spending on research can generate immediate returns in terms of commercial applications, university start-ups, spin-out companies and licensing of ideas and technology. But it also has a positive impact on private sector spending on R&D.

Fears are sometimes expressed that public spending of any kind 'crowds out' private spending: in fact, public spending on R&D 'crowds in' private spending on R&D. Not only is more private R&D done when public R&D increases, but that private R&D is more productive. The reverse is true too: reductions in public R&D reduce private R&D.

Alongside publicly available research results, universities provide much else of value to the private sector, including staff training, consultancies, conferences and contract research. Most of all, they produce an essential resource for business and industry: highly trained graduates. (In addition, the UK's universities are a significant source of export revenues via the many overseas students they attract.)

The combination of new knowledge, top quality researchers and highly skilled graduates that universities produce is not only beneficial to UK firms. It also attracts inward investment by foreign-owned companies, which has many benefits for the UK economy.

This begins to suggest answers to the third question of why it is so essential to sustain current levels of public funding for research in the UK? Continued public investment in scientific endeavour is essential for the success of UK business and industry for the following reasons:

- Geography still matters: the UK needs to be doing frontier research to generate local development around its universities, both through attracting inward investment and encouraging local innovation and local new businesses.
- Absorptive capacity is vital: the UK needs to be doing frontier research to be able to take advantage of frontier research being done elsewhere.
- Skills: the UK needs to be doing frontier research to attract and retain world-leading researchers and to continue to build a high-skills economy. As argued in Lord Sainsbury's 2007 review of UK science and innovation policy, the UK cannot win a 'race to the bottom'.

The Sainsbury report provides a cogent summary of the case for sustained public investment in UK science:

> "The UK should be a country famed for its innovation as well as its outstanding record of discovery; a country that invests in business R&D, education and skills, and exports knowledge-intensive goods and services to the world. We should seek to be a country that enjoys strong science and technological links with the best research around the world, so that we can stay at the cutting edge. The UK should be the partner of choice for global businesses looking to locate their research, and for foreign universities seeking collaboration with the science base or business."

> "Finally, we should be a country to which talented entrepreneurs and world-class companies come from around the world to perform research and set up high-technology companies, attracted by the quality of our research, by the strong links between our universities, research institutes and industry, by geographic clusters of high-technology companies, by their ability to raise finance, particularly venture capital, and by our quality of life."

> "It is not possible to predict where the new jobs will emerge in the future but it is possible to see many opportunities for UK companies to create new products and services, and new industries in areas as diverse as aerospace, pharmaceuticals, biotechnology, regenerative medicine, telemedicine, nanotechnology, the space industry, intelligent transport systems, new sources of energy, creative industries, computer games, the instrumentation sector, business and financial services, computer services and education."

> "At no time since the Industrial Revolution has the restructuring of global economic activity been so great, and we need to accept that China and India are now seeking to upgrade their industries. We can be one of the winners in 'the race to the top', but only if we run fast."

The Sainsbury report was written before the financial crisis, the economic recession and the budget deficits that demand constrained government spending. But even in straitened economic times, the arguments remain compelling. Short-term retrenchment may be needed, but significant reductions in research funding could have very damaging long-term consequences for the UK economy.

In his UUK speech, Professor Steve Smith made the following analogy:

> "Cutting back on the UK's R&D base now would the equivalent of the government cutting back on the production of Spitfires in the early summer of 1940."

This view is particularly striking in light of the very different policies being pursued by many other OECD countries, which are in comparable fiscal difficulties, but which are responding by increasing not reducing their public spending on research. Professor Smith's conclusion indicates that research is indeed our future:

> "It is absolutely imperative for the future of this country that the UK remains a first-rank knowledge economy, not for the sake of universities, not even for the sake of current and future staff and students; no, the UK has to remain a leading knowledge economy because there literally is no other choice if we want to bequeath economic prosperity to our children."

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