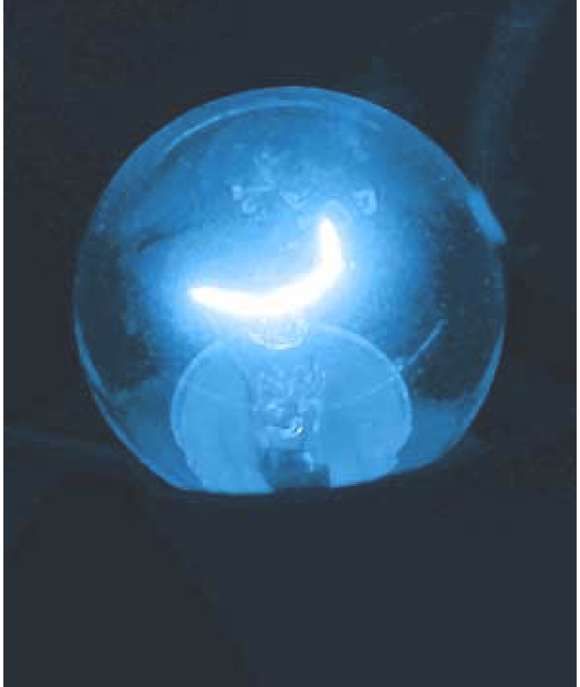

MARKET-LED INNOVATION CENTRES

A NEW MODEL FOR UK INNOVATION

Dent Associates
Science in Business

This report is intended primarily for policy makers but it will also be relevant and of interest to executives of Higher Education Institutes, research institutes, Technology Innovation Centres, science-based companies and a wide range of professionals, researchers and entrepreneurs involved in technology transfer, contract research and SMEs.

Dent Associates
Science in Business

Dent Associates Ltd: a global food security and climate change consultancy, providing advice, partnership and training for small to medium enterprises on business strategy and development, government affairs, export, international partnering, innovation and technology validation.

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Every effort has been made to ensure that the information presented in this publication is correct at the time of publication. Collation and preparation of the content was carried out by David Dent and Mike Theodorou, with editing and proof reading by Catherine Dent. The publication was formatted and designed by Alun Phillips of BeanCreative (beancreative.com.au) and Published by Dent Associates Ltd.

Acknowledgements

Our thanks to Bruce Alexander, Jayne Brookman, Phillip Keenan, Hadyn Parry, Brian Pettit and Joe Ross for the discussion and debate that led to the writing and preparation of the following report. Special thanks to Jayne Brookman, Steven Broome, Steve Adams and Brian Pettit, for their contribution and comments on the manuscript. Thanks also to Alun Phillips of BeanCreative for the design and formatting of the document.

Preface

Thomas Kuhn's use of the term paradigm in science has moved into common parlance to describe how there is a tendency to think and reason in a particular way prescribed by a normal standard. The converse argument of 'thinking outside the box' breaks the standard conventions, often leading to a change in approach, or in scientific terms, a paradigm shift. It should not come as a surprise to anyone to appreciate just how much we all accept and contribute to the normal conventions in our disciplines or areas of expertise. This is because it makes it easier if we accept and focus on certain norms in order to enable us to challenge others. With the subject of innovation it could be that we in the UK have simply become too engrossed in technological and science-supply-led innovation to the detriment of other 'non-science' areas which can also contribute significantly to the introduction and development of new and novel market-led innovations. This view, of our general inability to recognise the necessity of a paradigm shift towards market-led innovation became apparent in discussions had by a group of scientists and businessmen and women who by chance came together on a UKTI supported visit to Brazil in October 2010, on the occasion of the Joint Economic and Trade Committee Chaired by the Secretary of State for Business Innovation and Skills, the Right Honourable Vince Cable MP. In discussions held over a number of evenings, thoughts coalesced into a one page document that we referred to as the Sao Paulo Protocol which formed the pre-cursor to the following report. In essence the report is evidence-based, suggesting an alternative to the norms of science-supply and technology-push from the science and engineering base to improve our ability to deliver market-led, business focused innovation from across the whole of the UK research base.

David Dent
Mike Theodorou
March 2011

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Executive Summary

The UK economy needs innovation to drive its recovery. The emphasis on delivery of innovation to the business community is science supply-led and focussed in the HEI sector. Delivery concentrates on technology development in order to generate radical innovations. It utilises a limited range of organisations that can contribute to innovation and a subset of the potential skills base of UK HEIs. The evidence base suggests that this approach is limiting our ability to bring a wider range of innovations to the business community.

A new model of innovation is proposed focussed on the market, whereby a market sector is defined by the range of business types, business models and processes, products and services, information needs, technology use, attitudes to innovation as well as consumer needs, trends and demands operating within the sector. The new model of innovation will require the formation of Market Innovation Centres (MIC), largely by re-focusing existing university and related HE business centres. We propose the new model as a cost effective, highly flexible business and market focussed approach to innovation. The MIC's identify gaps and opportunities for generating intellectual property, new start-ups, market intelligence and consultancy opportunities. They are able to achieve this through methodologies which embrace market gaps. Their activities will contribute to the generation of novel products and services, innovative business models, market positioning, organisational and structural innovation as well as new processes and supply chains. In this model, science and technology is applied as a tool to generate new products, processes and services to meet previously identified and specific gaps and opportunity in the market place. This report recommends the following:

- Review of the UK Innovation Policies, Systems and Infrastructure with the view to enable the incorporation of market opportunity which prioritises innovation relevant to a broader range of innovation players
- Incorporate into UK Innovation Policies the ability to build on the current emphasis on technology with a wider range of innovations that include new business models, market positioning, organizational, business processes and supply chain innovations.
- Promote the establishment of MIC's across the UK to improve the delivery of innovation particularly for the 95% of UK companies which are SMEs
- Refocus and re-align a proportion of our research base to conducting market-led scientific and engineering research commissioned on the basis of the need to innovate to address market gaps and opportunities.
- Creation of new, or modification of existing, funding mechanisms to enable MIC's to commission market-led R&D to develop specific market defined innovations
- Establish a short-term, time limited capability to assist in promoting and creating MIC's as part of the mandate of the TSB
- Ring-fenced, directed use of HEIF to facilitate establishment of MIC's at key HEI's
- Build in MICs or market innovation units as part of the mandate of Technology and Innovation Centres (TIC's)
- Allocate short-term funding to facilitate Venture Capital and Private Equity Company engagement with MIC's through the British Venture Capital Association and other relevant bodies

Introduction

There is general agreement that innovation is linked to economic growth for individual business and the nation as a whole. From this is derived the rationale for governments to identify and prioritise policies to catalyse and support innovation across their economic base. Where policies succeed, the benefit to a nation's economy can be considerable. The USA has been successful in this regard particularly with, for example, the rapid commercialisation of semiconductors, computer and internet technologies (Hauser 2010). By contrast, the UK, while considered as an inventive nation, is somehow less effective at commercialising and generating wealth from its creativity (Bitichii & Ates 2009; OECD 2010). Evidence suggests that the UK is relatively poor at translating HEI generated technological research into products and services of commercial value and that there is a need for change. However, even if accepting of this need, it will take time to transform the UK to enable it to innovate more effectively. This is because, it is not only about introducing appropriate infrastructure and funding support mechanisms, but also about changing the culture of innovation which in the UK is largely science supply-led as opposed to market-led (Dent 2010).

The global economic downturn has generally diminished economic growth and if the UK is to pump-prime innovation-led growth in support of its economy then the country needs to continue to do what it is good at and address quickly what it is not so good at (OECD 2010). While innovation has increasingly become more important as a key part of the UK's economic policy agenda (DTI, 2003; Brown, 2008), there is now a paramount and pressing requirement to deliver something of significant economic value within the next few years. However, policy changes that emphasise technology development and which are introduced now will take many years to have a significant impact. Therefore there is a need to be open to all opportunities to build and capitalise on different types of innovation to drive forward business growth.

Numerous policies to drive innovation have been introduced over the last two decades. In general, these policies tend to emphasise linkage between university and business in an attempt to increase the commercialisation of by-and-large, publicly funded research (OECD 2010). Measures taken include (a) increased research funding, (b) enhanced science park investment and (c) mentoring partnerships between universities and businesses. At local and regional levels, innovation strategies include the creation of

Technology and Innovation Centres (TICs) to enable industry to exploit new and emerging technologies. At the national level, the Technology Strategy Board (TSB) and Knowledge Transfer Networks (KTNs) were created, designed to foster development in key technology sectors (Conway and Steward 2006; Tidd 2006). The KTN were established to improve knowledge flow in key sectors such as aerospace and defence, bioscience, digital systems environmental sustainability and materials.

Large commercial organisations have their own R&D capability or the ability to outsource research, whereas very few SMEs have such capacity. Interestingly, whereas SMEs represent >95% of all businesses in the UK and account for over 60% of employees, 60% of all research income from commercial business to HEI's actually comes from non-SME companies (HESA 2010). This demonstrates the need to identify more innovative ways to assist the SME sector better in this regard.

A wide range of technology transfer and business support instruments have been introduced, including one of the key drivers for change, the Higher Education Innovation Fund (HEIF). The HEIF was established in 2002 to incentivise knowledge transfer from universities to the private sector. Among other benefits, HEIF has mandated universities to deploy strategic plans for business support, to set up enquiry points for SMEs, and to generally expand support for SMEs (Galsworthy & Knee, 2007). The role of SMEs in driving forward economic growth through innovation is crucial. As a sector, they are often more flexible and entrepreneurial than larger companies in their approach to the market and their ability to adapt to the challenges that it presents. Recent schemes through the TSB have included proof of concept short-term funding for SMEs and micro-businesses. As a consequence of this and other initiatives, most knowledge transfer indicators score positively in relation to enhanced knowledge transfer from HEI to business sector (Webber 2008).

Government policy to support innovation has increasingly been concerned with enabling better connections between the many small firms with technological needs, and the major research and technology institutes and universities, which might be able to meet these needs (Tidd 2006). Science Parks represent one of the first initiatives to co-locate technology-focused businesses alongside academic endeavour in order to facilitate the transfer of ideas, generation of new opportunities and scientific collaboration. These parks are now a familiar part of University infrastructure and serve as a means of revenue for research intensive small companies and for the university, as facility provider and lease holder.

Many of the changes introduced to UK innovation policy have been driven by various reports perhaps most importantly, the Sainsbury Review of Science and Innovation (Sainsbury, 2007) and the UK's first dedicated innovation White Paper, Innovation Nation (DIUS, 2008). The Royal Society's report, The Scientific Century, places science and innovation at the heart of the UK's long-term strategy for economic growth. The Council of Science and Technology the highest strategic scientific body in the UK, produced a report A Vision for UK Research (2010), while the Hauser Report (2010) focussed on the role and value of Technology and Innovation Centres. However, none of these reports fundamentally questions the principles or the paradigm on which so much of UK innovation policy is based.

The sheer volume of initiatives and the activities they have generated is testament to the previous UK government's commitment to innovation. However, with a new coalition government in place, it is appropriate to review and assess the success of these policies and instruments and to determine where gaps and opportunities remain to be addressed. In order to do this, it is first necessary to describe in some detail the innovation process and to test some of the assumptions on which our current infrastructure has been based; an analysis of which is included in the Appendix. It is then appropriate to review how alternatives and additional measures may be implemented.

The Evidence Base for Model Failure

The UK has placed the science and engineering carried out at its HEI's at the heart of its innovation policy. The priority afforded "blue skies" research, exemplified by excellence in science, publication and citation in high impact journals has encouraged the development of platform technologies or technologies which underpin a wide range of applications, often spanning many business sectors. Such 'step-function' discoveries can enable the creation of new markets, or result in significant changes in existing markets. However, the intellectual property generated by such discoveries tends to be very difficult to capture, control and translate into economic benefit for UK plc. Interestingly, according to UKTI statistics, overseas organisations own over 35% of patents in the UK (compared to 12% in the USA and 4% in Japan). UK investment in research is rarely translated into measures of economic value for the Nation - and the evidence for this is reviewed in Appendix I and summarised below.

In 2008/09 £4,144 million worth of research grants and contracts was available from all sources, for UK research at the 160 UK HEIs (HESA 2010). £1,531 million of this was provided by BIS Research Councils, the Royal Society, British Academy and the Royal Society of Edinburgh. In the same year, £732 million, was allocated to collaborative research funding between the HEIs and non-academic industry-based institutions (HESA 2010). From this substantial investment an income of £56 million was generated from intellectual property. Using only the £732 million figure for collaborative research with industry as a base line it is evident that:

- spin-off companies cost an average of between £3.8 to £38 million to establish (depending on method of assessment)
- each spin-off company generated on average £290K in income
- each patent filed cost on average £349K to produce
- each patent granted cost on average £1.1 million to produce
- only 0.04% of the 139,784 FTE employees of HEIs created a spin-off company
- only 1.5% of HEI staff were involved in research that could be patented

In addition by way of example, the Biotechnology and Biological Sciences Research Councils (BBSRC) total grant-in-aid for the period 2005-09 was £1,488 million.

In 2008/09 the BBSRC Core Strategic Grants to its eight institutes was £56,326 million with an additional £6,842 million provided as Research Initiative funding and £12,145 million as Responsive Research Grants (BBSRC Annual Report and Accounts 2008-2009). Over the period 2005-09 the BBSRC sponsored institutes generated:

- £2.9m in license income
- 98 licensing agreements with UK companies
- 255 breeders rights agreements and patents that generated an income
- a total IP exploitation income of £6.2m from IP which cost £1.9m to protect;

The BBSRC also sponsored commercialisation activities at Universities, valued at £115 million; an investment which generated £7.2 million in exploitation income and 97 spin-out companies over the period of 2005-08.

For a nation that is basing its future prospects on an innovation-based economy secured from our public scientific research base, by any normal business criteria, these statistics do not make good reading. This is not to say that there is no additional value in the research conducted. However on the above statistics alone, it cannot yet be claimed that our public research institutions represent the innovation engine of the UK economy.

Innovation models

The priority afforded science and engineering research in order to create an environment for technological innovation (see Appendix I) has tended to ignore the reality of innovation for businesses, which is not solely reliant on technological innovation or new products or services for improvement in turnover, profitability and growth. A comprehensive study by Little (2005) demonstrated that in business, the highest ranked barriers that stand in the way of better innovation performance are a lack of internal resources and limited market intelligence. Little (2005) concluded that the best industry innovators expect a range of returns from innovation but consider the effective meeting of customer needs as the most important, followed by efficiency of manufacturing, reduced product costs, innovative brand equity, new products for niche markets, improved efficiency of R&D, shortened time to market, creating new customer needs, new products for broad groups and modernisation of products. These factors may require innovation to generate a return but certainly do not rely on technological or product innovation to achieve it. However, in relation to innovating to create new products, companies ranked the following processes as most important: market intelligence, product development process, strategic planning, technology and resource management and lastly idea management. Interestingly however, analysis of these same processes for actual impact on company sales, placed idea management as having the biggest impact on sales of new products, whereas market intelligence had the least impact.

Attempts to classify innovation have tended to emphasise the impact that they have and the extent to which they may be disruptive in the market place, based on the seminal works of Joseph Schumpeter (1943) who coined the terms radical innovation and its counter incremental innovation. Radical innovation denotes a process of creative destruction where innovations result in a technology or product that is so superior that existing products are rendered obsolete and their competence is no longer competitive.

By contrast, incremental innovation, the knowledge required to develop a product or service builds on existing knowledge, it is competence enhancing and with this form of innovation, most existing products remain competitive.

Radical innovation tends to be the holy grail because the scope and scale of the opportunity generated by displacement activity for new high impact products and services and economic returns is so high. This may explain the emphasis that is placed on technological innovation through use of scientific and engineering research because history would suggest that the rewards from such discoveries and developments are potentially much greater than from incremental innovation. However, scientific and engineering research are not the only means by which revolutionary innovations can be generated and the emphasis on technological progress achieved through scientific method alone could be limiting the range and type of innovations available. Categories of innovation that exist in addition to technological based products and services include:

- Business model innovation
- Positioning and market innovation
- Organisational innovation
- Process innovation
- Supply chain innovation

The conventional approach to innovation in the UK concentrates on technological innovation achieved through research in science and engineering. However, the additional types of innovation listed above, as well as product, services and process innovations, can be generated by other disciplines such as business and social studies, design and creative arts, all with their greater emphasis on end-users, social drivers and acceptability, human behaviour, ergonomics, organisational behaviour etc.

Evidence suggests that UK firms derive little turnover from innovation, particularly from new to market goods or services, relative to other European countries (OECD 2010). The UK is below the OECD average for new-to-market goods, although interestingly above average for utilising non-technological innovation. The UK appears to be better at utilising non-technological innovation than technological innovation relative to other European countries.

By emphasising traditional scientific R&D approaches to innovation we are limiting the scope and type of innovations that are being generated in the UK. And by limiting the type of innovation we are also limiting the potential economic value to UK plc.

The Innovation Process

For many years it has been argued that we need to translate research outputs into greater economic and (more recently) social benefits (CST 2010) and yet we appear to not yet hit the mark. One of the problems we face is that our current paradigm presumes a reliance on science, and science supply-led innovation. The decision making process behind science supply-led innovation has its roots in the Haldane principle (originating in 1904; the idea that decisions about research spending should be made by researchers). This has led, in the first instance, to an emphasis on scientific excellence as the most efficient and cost-effective route to scientific innovation. Consequently, our best scientific innovators are constrained within a system that is motivated by peer review publication and academic excellence rather than market and economic opportunity.

Science is primarily the preserve of HEI's and hence our Universities are seen as the key source of innovation and technology. Such University IP has a role to play, but its effect on local and national economic development is modest in the short to medium term (as highlighted in the Appendix I). The over-glamorised notion of the university boffin as the prime source of inventions that can rebuild the UK's scientific industrial base is seriously misleading (Connell and Probert 2010).

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Problem Solving and the Origins and Route to Invention

The production of ideas and how we use them to solve problems is the key to invention (Kirkham, Mosey and Binks 2009). In the last 100 years or so an increasing number of formal problem solving methodologies have been developed across a wide range of domains, from industry to advertising. George Polya's 'How to solve it' (1945) has been enormously influential far beyond its original domain of mathematics. TRIZ, the heuristic/algorithmic system developed by Genrich Atschuller in post war Russia is a problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature, and has a devoted following. In the area of creative idea generation, Alex Osborn's 'brainstorming' has entered the language as has Edward de Bono's 'lateral thinking'. Lumsdaine and Binks (2007) highlight the importance of recognising and balancing different thinking styles, and also placed particular emphasis on 'entrepreneurship' or, looking for a problem to solve (Kirkham et.al. 2009).

Although not generally recognised as such, research is a problem solving enterprise. Hypothesis testing assumes a possible explanation to the problem and tries to prove or in some contexts (the null hypothesis) disprove the assumption. Scientific research can be viewed as employing existing ideas or adapting existing solutions to similar problems. It is in effect an organised and systematic way of finding answers to questions - of solving problems. Research is characterised by a definite set of procedures and steps which are followed in order to get the most accurate results. It is not spontaneous but is a planned, often reductionist or sometimes holistic procedure - one that is focused and limited to a specific scope with a focus on relevant, useful, and important questions for which answers are sought. Scientific method has become the dominant form of problem solving in the UKs systems and processes of innovation.

Invention can arise as an idea for which its application provides a solution to a problem. Invention may also arise by identifying a problem that requires an idea to generate a solution. The traditional UK research approach tends to emphasise the former; identification of a scientific problem for which a scientific solution is sought. In this context, the solution may or may not solve a market problem and is 'scientifically' of secondary consideration. The opposite to this approach is to identify a market problem and use science to develop an innovative solution. This approach recognises that research can take many forms and that innovation need not be based on a scientific or technological solution. The approach recognises that for innovation, market research and other ideation techniques are initially required to identify opportunities (problems) for which science and technology may or may not be required to deliver a solution.

We tend to think in terms of market as the group of consumers or organisations that is interested in a particular product or service and have the resources to pay for it. Market research in this context is the analysis carried out to profile the potential customer, their purchasing characteristics etc. However, the market that we are considering here is the market for innovation - which is wider than the traditional consumer focus and is defined by the range of business types, business models and processes, products and services, information needs, technology use, attitudes to innovation as well as consumer needs, trends and demands operating within the sector. However, the techniques and approaches used to understand consumer needs are applicable to the market for innovation.

Table 1. Methods and approaches used in business to generate ideas for product innovation (Cooper and Edgett 2008).

Voice of Customer Methods	Open Innovation Approaches	Other Innovation Methods
ethnographic research	seeking ideas from external partners and vendors	peripheral vision - review of external world to identify trends and threats
customer focus groups for problem detection	accessing the external technical community	monitoring technological trends for disruptive technologies
lead user analysis	scanning small businesses and business start-ups	patent mapping
customer brainstorming	external product designs	idea capture internally
customer advisory panel	external submission of ideas	
customer visit teams	external idea contest	
customer or user designs		
community of enthusiasts		

Cooper and Edgett (2008) identified 16 types of approaches and methods under three categories that are used in business to generate ideas for, in particular product innovation (Table 1).

Voice of Customer Methods represent a range of techniques used to capture a customer's expectations, preferences and aversions to products and services based primarily on the customers needs and wants. The Open Innovation Approaches by contrast are techniques used to seek the views of those in the industry, business, or technological sector who have some knowledge, involvement or expertise relevant to the sector. Other Innovation Methods represent miscellaneous techniques which have proved popular as idea sources. The different methods are listed against their respective headings in Table 1.

The Cooper & Edgett (2008) survey of 160 US companies identified that the most popular and effective methods used were customer visit teams, peripheral vision, focus groups, lead user analysis and disruptive technologies whereas, the least popular and ineffective were external product designs, external idea contest, external submission of ideas, scanning small businesses and start-ups, and accessing the external technical community. In essence, the least successful routes to innovation were categorised under the Open Innovation Approach heading where the approach is to consult for expert opinion. This is analogous to the science supply-led approach to innovation upon which much of our current system is based.

In summary, there are a range of techniques that can be used to generate ideas for innovations that range from approaches such as brainstorming and lateral thinking to scientific or social research and customer surveys. The variety of techniques available may be used by inventors, scientists, entrepreneurs and business managers but the use of each is largely confined to particular specialist know-how and disciplinary specific approaches. Scientists may use lateral thinking techniques but will largely exploit scientific method, observation and experimentation. Inventors may carry out little scientific experimentation but rely heavily on their own ideas, lateral thinking and their understanding of market problems. The business manager is less likely to look to generate new ideas through fundamental research, but will be accustomed to carrying out voice of customer research in order to gain good market intelligence.

Market Innovation Centres A New Market-Led Model for UK Innovation

The UK needs to revisit its current systems of science and technology-led innovation and put in place policies and processes that will:

- Prioritise addressing the innovation needs of UK SMEs
- Create a common currency between HEIs and the business community focussed on the market to enable closer, more meaningful collaboration
- Place greater emphasis on non-technological innovation as a means to improve business performance and economic growth
- Engage a wider range of innovators and innovation organisations outside the traditional emphasis on the HEI's
- Engage with a wider range of potential innovators from disciplines outside of science and engineering within the HEIs
- Provide relevant market information that will better enable SME companies to innovate and to collaborate with a range of innovators
- Prioritise processes which reduce time to market for technological innovation

Addressing these key issues will transform the system of innovation in the UK and subsequently impact positively on the UK economy. Market-led innovation provides a more direct, focussed and strategic approach to innovation that will generate immediate economic benefits as well as establishing a longer term infrastructure that will better link business and the non-commercial suppliers of innovation. The way to achieve this is through Market Innovation Centres.

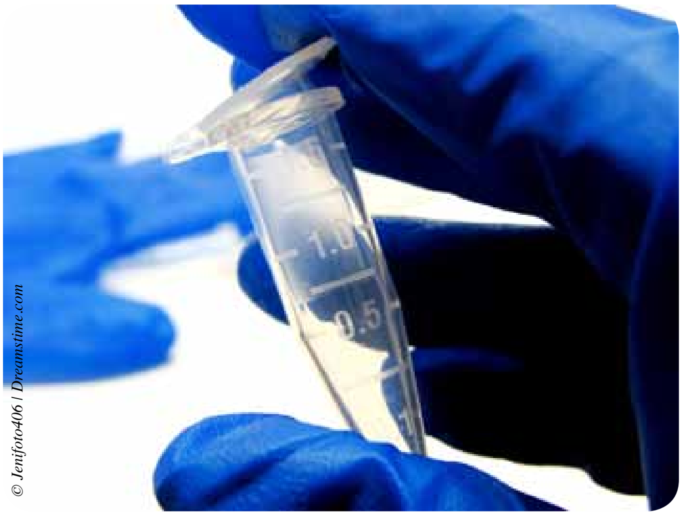
Market Innovation Centres (MICs) are centres of expertise in the collation and analysis of market, business and technological data to identify gaps and opportunities in the market and generate innovative solutions to meet these commercial opportunities. The solutions are broad-based and inclusive of science and technology solutions. The MIC's can be flexibly applied to suit a range of organisations but each should have the following key features and capabilities:

- identifying market gaps and opportunities in specific sectors defined in terms of existing products and services, types of business, business competitors and business models, features

- and designs, supply chains, customer needs, promotional opportunities and patent space
- identifying innovation opportunities which may be technological, products or services, organisational efficiency, business processes or new business models, supply chain requirements, product designs and marketing strategies
- generating market intelligence and innovation reports for SMEs and intellectual property of commercial value on which can be based consultancy services for businesses
- commissioning scientific and engineering R&D projects based on identified market need for a specific commercially viable innovation
- ability to generate spin-out companies and secure appropriate equity investment

Identifying Opportunities and Generating Ideas of Genuine Commercial Value

The ability to identify opportunities and generate ideas of commercial value from a market perspective requires employment of multidisciplinary teams which include entrepreneurial scientists, engineers, designers and social scientists capable of undertaking detailed market and business analyses. Their remit would be to study the scale, scope and customers for existing products and services, business models, product designs and business processes, promotional and organisational structures and supply chains in order to identify market and business gaps and opportunities. Their research will use a variety of appropriate techniques to identify emerging disruptive and incremental technologies and innovative product designs. Where gaps and opportunities are identified, solutions to meet these will be mapped and parameters of the innovation defined. Further development of the solution may require scientific and/or engineering research and design work may need to be commissioned.



The research carried out should generate market solutions having IP value and which would be available for licensing or the generation of spin-off companies. Commercial market analyses and know-how for businesses could be made available through reports or consultancy services. A market analytical approach which may in itself generate an inventive step with IP value but if not, the subsequent scientific or engineering R&D should do so.

Enhancing Commercial Collaboration, Spin-Offs and Speed to Market

The science supply-led approach to innovation too often discounts business or market needs and yet businesses are dependent on market information in order for them to innovate. HEI community and business sector work within different cultures that commonly acts as a barrier to effective collaboration. Market intelligence is the common denominator which can better link these two disparate groups and enable closer collaboration. Market information better informing and directing HEI research engagement with industry as well as providing a crucial resource for businesses, particularly SME's. MICs established in HEI's would provide a central resource that will inform both academic and industry parties and provide a common basis of understanding for promoting and encouraging greater dialogue. Such a resource can provide a route to a wider range of services such as contract R&D between the university and industry sector.

There is a greater need to be able to generate start-ups and provide new innovative solutions to gaps in the market that are of value to SMEs. MIC's enhance the opportunity for establishing new businesses because they are centres of knowledge on market gaps and the creation of solutions whether, technological, supply chain, business model or process based. In contrast to a science-led approach to innovation, requiring a technology to be relevant to, or need to be adapted to a specific market, the MIC market-led approach to technological development defines first the specifications and parameters for market entry before designing products to meet this need. Such clearly defined technologies addressing specific market gaps and opportunities will potentially have a reduced time to market - something of a priority during a period of economic recovery.

Extending the Range of Pertinent Host Institutions

The advantage of a market-led approach to innovation is that the expertise required, the cost of operations and their applicability to different funding mechanisms makes it accessible to a wide range of organisations. The approach does not require a massive investment of capital in infrastructure, buildings or laboratory facilities but rather can be incorporated into appropriate existing institutions with relevant expertise including university technology transfer offices or their outsourced equivalent, knowledge transfer network teams, soft companies - research and technology organisations, as well as technology and innovation centres. However, the asset base of a Market Innovation Centre will ideally need to include the following features:

- IP Management - patent processing and search capability for patent mapping
- Ability to create spin-off companies
- Ready access to diverse range of expertise to enable market/business analysis and evaluation of gaps and opportunities in the market to be assessed from a wide range of perspectives including voice of customer, open innovation and other techniques such as peripheral vision and disruptive technologies
- A suitably large financial asset base
- Ability to commission or undertake science, engineering, social or design research
- Entrepreneurial skills and know-how (knowing how to innovate)

In addition, access to undergraduate and graduate entrepreneurs will be desirable in ensuring a flow of capable and committed individuals with the drive to make a difference.

The Benefits of MICs to existing Organisations

HEIs, Soft Companies and Technology Innovation Centres will all potentially benefit from integrating market innovation expertise into their organisations through:

- Creation of a more market oriented culture
- Common currency created to improve communications and value offering between organisations and the business community
- Opportunity for new revenue generation e.g. consultancy and market intelligence reports
- Making use of a wider skills base across all disciplines
- Employing creative graduates and developing market oriented innovation graduate projects to work within and contribute their organisation
- Ability to generate a greater number of startups with increased chances of survival because they are based on a defined market gap.

A number of HEIs have a range of attributes that add value to the list above. For example, the Institute for Enterprise and Innovation at Nottingham University has a successful track record of research and teaching of entrepreneurship, particularly the different processes of ideation and for this reason an MIC would fit with the culture of the organisation as well as complementing existing training. HEIs who are able to complement their own expertise through collaboration with a range of other organisations, such as the Norwich Research Park (which brings together the UEA, the Norwich and Norfolk University Hospital, the Sainsbury Laboratory, John Innes Centre, The Genome Analysis Centre, the Institute of Food Research, PBL Ltd), are able to generate a cross disciplinary approach and culture which could be underpinned by an MIC. Groups of Universities, such as the 13 HEIs of the Universities West Midlands, who work together in a region, may benefit from the addition of an MIC which could focus collaborative activities on regional markets served by their combined expertise.

Soft Companies (Connell and Probert 2010) have increasingly been demonstrated to play a key role in the UK innovation process, particularly where technology business clusters are created, in areas such as Cambridge, Norwich and Oxford. Such clusters have arisen through the Governments commitment to enable technology focused businesses to flourish. Market innovation expertise would readily fit with the more market focussed Soft Companies providing additional revenue sources and the opportunities to create more start-ups.

There are about 50 business focussed TICs and these have received over £150 million in public support since 2008 (Hauser 2010). As Hauser (2010) acknowledges the TICs are intended to be mission driven organisations that develop their own in house knowledge and capability and work closely with leading Universities, industry and other TICs including public sector funded R&D and innovation programmes. TSBs new drive to create sector specific Technology and Innovation Centres should have a key role in integrating the interests and activities of universities and businesses. In order to achieve this then there will be a need to be open to differences in communication styles and culture which reduce the effectiveness when disparate specialists attempt to collaborate. Socio-cognitive frameworks used to bring such disparate groups together have demonstrated over many years and circumstances that a common language, modus operandi, and targets have to be secured, as the lowest common denominator for collaboration to be effective. Higher levels of integration are usually only achieved when common standards of proof are adopted, shared conceptual understanding and a recognition and appreciation of the role of each player, combined with use of appropriate models and good leadership (Dent 1992; Dent 1995). This alone will test the effective functioning of such TICs. If the TICs are capable of providing market intelligence relevant to both HEIs and business, this will provide an interface and sound evidence base for promoting collaboration.

MIC Costs, Funding and Investment

As is evident above and from the analysis in Appendix 1, the public investment in science and engineering yields a limited benefit to the nation in terms of the different measures of innovation; cost per spin-off company, number of patents, and commercial income generated, and not least, the type of company that are the main beneficiaries. At a time when it is difficult economically to justify further investment in research and development, to support large companies who can afford their own R&D, investments must be better targeted and based on the probable return to the nation - it has to be about bang for buck in terms of innovations which will generate a commercial return in an appropriate and relevant time scale. One of the significant benefits of the MICs outlined above is that they do not require major investment in infrastructure or high capital costs in order to secure a mechanism that will yield measurable benefits to the UK economy.

There are a number of existing funding mechanisms that can be redirected to the establishment and support of MIC's. In the HEI sector, the HEIF could be used for this purpose, indeed a ring-fenced sum could be identified specifically for this role which could be made available on the basis of a suitably structured business plan.

MICs are innovative centres of expertise generating ideas, concepts, models, processes, products and services which have intellectual and commercial value. Some of the IP may be protected. In addition, market assessments of industry sectors and other forms of market intelligence will be generated which will have commercial and intellectual value which may be patented or protected in conventional ways. In this way, the MICs will themselves be of commercial value and if established in appropriate ways could be eligible for and attractive to investors. Thus, a number of potential and existing funding mechanisms are available and pertinent with directed support from government to enable exploitation of a whole new form of innovative capability with in the UK.

Case studies which exemplify the new MIC Model of Innovation

The following case studies exemplify the value of the market-led approach to generating different types of innovation that have created new business processes, models, technologies and supply chain improvements. The first case study, is an example of how science supply-led technology development can fail when a market has not been properly defined.

Case Study 1

The Market Failure of Speed-Up - a technology without a market

In 1995 a spin-out company from the University of Wales, Cardiff undertook research into the use of amorphous silica dioxide as an adjuvant to increase the effectiveness of pyrethroid insecticides for the control of cockroaches. The silica dioxide works through absorbing the protective wax layer of the insect cuticle allowing more effective penetration of the chemical insecticide. Thinking around the problem the company's Product Development Manager David Dent, realised that there were similarities between the wax layer of an insect cuticle and that of a plant. A series of experiments in the greenhouse and in the field demonstrated that the silica dioxide improved the effectiveness of a number of common garden herbicides against common lawn weeds and a patent application was submitted. The amorphous silica dioxide product formulation was launched under the name Speed-Up and was ready for sale via UK Garden Centres where it was believed the product would be successful. However, when sales failed to meet expectations more detailed market research indicated that because the garden herbicide market was a crowded, complicated market which confused the consumer, the addition of an adjuvant which had to be added as a tank mix only complicated and confused things further.

Speed-Up was well conceived technology, was developed into an excellent product, met a market need in improving performance of existing herbicide, dramatically improving their performance and yet was not purchased by the consumer because the perceived market did not reflect the real market and consumer use. The market is not always what it is perceived to be - and only good market intelligence can identify the combination of business, technological, environmental, social and behavioural factors that create a market for a new product or service.

Case Study 2

Charitable Sector Market-led Innovation - The Pennies Foundation - a new process

Innovation in the Charitable sector in the UK has plateaued over the last few years as the great efforts of the last three decades have been applied to creating new ways of generating funding and securing donations from the general public. These include, charity shops, sponsored and televised events, sale of wrist bands, red noses, affinity cards etc. However, their remains a reluctance among UK donors to give money on a regular basis in a planned way in contrast to US givers. In the UK the most popular means of giving occurs on a spontaneous basis in cash street collections and yet because of the inefficiency of this method, the overall sums generated are relatively small. In 2005, the idea for rounding-up credit and debit card transactions at point of sale, with the electronic change being donated to charity was considered by the company Votiva Ltd. The rounding-up of transactions to the nearest whole denomination is not a new concept but through analysis of the market the application of this principle at point of sale using PIN terminals in a way that was not card dependent, was identified. The scheme is being launched through the charity, The Pennies Foundation and has the potential to generate substantial income for the charitable sector. This new mechanism was only possible however, because of the recent introduction of Chip & PIN terminals at most UK retailers as a means of enhancing card transaction security. This radical/disruptive innovation allowed for the first time, through use of electronic payment transfer, to simplify the process of giving so that UK consumers have the opportunity to give spontaneously every time they purchase goods at a retailer. The spontaneous nature of UK giving and the opportunity to 'round-up using chip and PIN come together to create an novel, innovative way of donating to charity; an example where a technology first – pipeline approach would have failed.

For further information see www.thepenniesfoundation.org; www.pennies.org.uk

Case Study 3

Market-led innovation in science-based agribusiness sector - designing new technologies

The mulitnational agrochemical companies have dominated the agricultural inputs business for 50 years with an approach based on screening thousands of molecules for those that may have biological activity and beneficial properties as new pesticides. This model of R&D based on screening novel molecules has proved increasingly costly and less effective over time as molecules meeting today's more demanding environmental and safety requirements have become increasingly stringent. The fertiliser industry has also changed little in 50 years using natural resources in their manufacture, formulation and widespread application as nitrogen, phosphorous and potassium (NPK). Agrochemical inputs of all kinds are now required to meet more stringent needs for sustainability, operator safety, reduced pollution and environmental hazard, consumer health, as well as to mitigate against green house gas emissions, while still fulfilling their role as effectively, or better than, conventional chemicals.

A different approach to developing agro-inputs has been pioneered by a company called Plant Impact plc who analyse the market to define the parameters and properties of products which will meet the needs of consumers and sustainable agriculture. They then cleverly design products based on current knowledge of plants, soil, farming practises and costs to meet these needs. Plant Impact have taken all of these new market factors into account in the design of a safe and effective pesticide based on essential plant oils; a calcium treatment which increases calcium content of fruit, can be applied at lower rates (using less water and reduced operating costs) and moves within the plant fifteen times faster than existing calcium products; and a nitrogen technology which is as effective as N but can be applied at lower rates, stays in the soil longer, reduces run-off as a nitrate pollutant and nitrous oxide gas emissions while improving crop yields. By taking a market-led approach to scientific research it has been possible to design appropriate technologies to meet demand in this new era of clean technologies for agriculture.

For further information see www.plantimpact.com

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Case Study 4

Market-led innovation in the publishing sector - a new business model

The music, book publishing and magazine/newspaper print publishing sectors work to different business models. By analysing the markets for different types of print product and how this applies to internet publishing a new publishing business model has been developed for magazine readers by a start-up company, ADG Publishing Ltd. This innovative company realised that the highly differentiated and segmented magazine market actually has some similarities with the music industry, except in the former authors are paid in advance for material and have no stake in whether or not the reader likes their work, whereas in the latter performers - the musicians, receive a royalty on every song sold and hence, their popularity determines levels of revenue. With their internet service, Yarida, ADG Publishing Ltd have created a means by which magazine readers can chose their own content by author who receive payment on a royalty basis, so that the more popular authors will sell more articles and hence generate greater revenue. Yarida also provides the opportunity for magazine article authors to create a profile and become personalities in their own right generating loyal readership in the same way that book authors and musicians currently do. Hence, through an analysis of the publishing business sector, current business models and comparisons with other media sectors, a whole new way of publishing magazine content has been created.

Case Study 5

Market-led innovation in the agricultural sector - a supply chain innovation

Supply chain innovations can significantly improve the efficiency and cost effectiveness of supply for a company with concomitant impact on financial margins and returns. Hemp is a low input, fast growing crop, which can be grown on a range of soil types, the fibres are used in industrial applications such as the automotive and construction industries. As a result of field based activity in 2009 carried out by In Crops Enterprise Ltd (a knowledge transfer organisation) and their increasing familiarity with the supply chain it became clear that a major impediment to the utilisation of hemp was the availability of an appropriate harvesting technology. With funding support from East of England Development Agency (EEDA) InCrops commissioned West Norfolk engineer Stephen Eyles to develop a fuel efficient, high-capacity multi-bladed hemp harvester capable of cutting at high speeds. The new harvester has three blades, which cut the crop into three lengths, which makes it easier to handle for baling, is powered by a tractor which is more economical than a heavy duty forager which in trials uses four times more fuel and harvests only half the area of crop in a day. By understanding supply chain constraints, and defining the parameters of a technology to remove the constraint, a harvesting machine could be designed and developed.

Conclusions

Market-led innovation and the different types of innovation this can create is grossly under represented in the current UK innovation system which relies too heavily on engineering and science supply-led research undertaken at HEIs. Diversifying the types of innovation available, relevant to SME's in particular, and the range of organisations able to deliver market-led innovation may be addressed through Market Innovation Centres. Such MICs can be flexible in their remit, their funding and outputs relevant to their host organizations, which may range from HEIs, TICs, Soft and Hard R&D organisations and companies - in this way negating high infrastructure costs and the need for significant public investment. Indeed, because such MICs can themselves generate intellectual property they have the potential to secure revenue through sales of market intelligence and consultancy as well as licensing opportunities; all of which will also be of interest to private investors.

The MICs also have a added benefit of creating a wider range of sector specific indicators of innovation such as figures on market gaps and opportunities, patent gaps and spaces, potential new business models and processes, new designs as well as innovation outputs (number of patents, start-ups and spin-offs etc); the combination of which facilitates measures of efficiency of uptake and translation into commercial value.
The emphasis on undertaking scientific research to develop a technology or product to meet a specific market gap or opportunity will focus research effort to deliver to a pre-defined need and shorten time to commercialisation. When combined with a wider range of business performance oriented innovations this will have an immediate impact on business growth and subsequently, the nations economy.

Recommendations

On the basis of this report a number of recommendations become self-evident including the need to:

- Review of the UK Innovation Policies, Systems and Infrastructure with the view to enable the incorporation of market opportunity which prioritises innovation relevant to a broader range of innovation players
- Incorporate into UK Innovation Policies the ability to build on the current emphasis on technology with a wider range of innovations that include new business models, market positioning, organisational, business processes and supply chains
- Promote the establishment of MICs across the UK to improve the delivery of innovation particularly for the 95% of UK companies which are SMEs
- Refocus and re-align a proportion of our research base to conducting market-led scientific and engineering research commissioned on the basis of the need to innovate to address market gaps and opportunities - preferably those which have been defined by analyses conducted by MICs
- Creation of new, or modification of existing, funding mechanisms to enable MICs to commission market-led R&D to develop specific market defined innovations
- Establish a short-term, time limited capability to assist in promoting and creating MICs as part of mandate of the TSB
- Ring-fenced, directed use of HEIF to facilitate establishment of MIC's at key HEI's
- Build in MICs or market innovation units as part of the mandate of Technology and Innovation Centres
- Allocate short-term funding to facilitate Venture Capital and Private Equity Company engagement with MICs through the British Venture Capital Association and other relevant bodies

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Science Supply-led Innovation The Evidence Base for Model Failure

The UK has placed technology development through promotion of our scientific and engineering research base at Higher Education and Research Institutes (HEIs) at the heart of our Nation's innovation policy. In addition, a number of national research institutes exemplified by the BBSRC sponsored institutes, play a significant strategic role which encompasses the need to use scientific innovation for national economic and social benefit.

There are a number of means by which to gauge the value of scientific and engineering innovation in relation to economic impact:

- performance in the publication of scientific papers and citations relative to other nations is commonly cited as a indicator of innovation
- macro estimates based on improved production output nationally and globally (although such approaches are limited by the multiplicity of factors that may have contributed to improved output) e.g The BBSRC-sponsored John Innes Centre is estimated to have helped increase UK wheat production by £75 million per annum and as much as £4.6 billion per annum worldwide
- estimates of the cost of prevention had a new scientifically developed solution not been available e.g. The Institute for Animal Health research on bluetongue which with an investment of only £45 million saved £485 million per annum through prevention of outbreaks
- arbitrary estimates of the potential value of improved products or techniques e.g. Research at the Institute of Food Research contributes to >£100 million per annum through improved techniques to chill food, methods to extend shelf life, and through reduction in cases of food poisoning
- outputs indicative of economic value such as number of start-ups, patents, licensing agreements, income related to sale of IP etc.
- a whole series of indirect estimates of impact such as number of individuals trained, availability of information, media releases, public meetings and events, financial efficiency, number of collaborative activities etc.

The UK has a world class reputation in science (second only to the USA). This is reflected in the total number of papers it publishes worldwide compared with other nations. In the paper The Scientific Impact of Nations published in 2004, Sir David King used citations to highlight the quality of UK science relative to that of other nations. This comparison has been made over the intervening years with the UKs share of world citations rising to 11.8% in 2008, with 14.4% of the top 1% of most highly-cited papers. The UK has 12,776 papers among the world's most highly-cited 1% for 1999- 2008 with an average impact of 153.2 citations per paper. The UK's contribution is about 25% of the EU total (Evidence 2009). A recent survey conducted in June 2010 for the Times Higher Education by Thomson Reuters, which ranks each of the G7 countries in 20 scientific subjects, concluded that the UK is first in six subjects and no lower than third in any. By comparison the US is first in ten subjects, but its average ranking is only slightly higher than the UKs (Jump 2010). However, while a measure of scientific excellence, such indices of scientific output are not necessarily the most appropriate indicators of economic value or impact.

Generally, in order to measure economic impact it is first necessary to define the value of the input followed by the corresponding value of the output. In a normal business situation one would identify the size of a market and the investment required to meet this with a new product or service and subsequently consider how the revenue generated and the market share captured has delivered, relative to the cost of the investment. With research the only input measure we have is the amount of money invested, for other than with strategic research (and even then), it is argued that it is difficult to identify the market size. This is because the research under taken is science supply-led rather than market-led, and we can never be 'certain' of the value of a scientific output or its subsequent impact. This is particularly true of so called "blue skies" research.

On the outputs side of the equation, it is argued that because of the complexities and long time frames involved it is not straight forward to identify how such research investment translates into economic impact. While it is possible to have some empathy with this notion, and to understand the multiplicity of factors that may be involved, the argument itself is self fulfilling because of the way research is undertaken. Science supply-led research carried out to answer scientific problems, rather than address market problems (market-led science), has no prescribed output within a fixed time frame. Therefore, it is not possible to measure just how successful it has been. However, the UK has been investing in its science and engineering base with a view to promoting economic impact for some considerable time. Innovation has been a priority of governments now for nearly twenty years and certainly efforts have intensified since the beginning of the 21st century. Hence it is not unreasonable to expect that a snap-shot of the current of state of play, in terms of measuring investment against outputs, might yield an indication of the impact of our drive to generate an innovation based economy. Outputs most relevant in this context are those of number of start-up businesses, income generated from intellectual property and measures of intellectual property; patents and licensing agreements.

The following analysis takes such a snap-shot of the UK research input and innovation outputs over 2008/09; the years for which we have the latest data in order to determine whether or not science and engineering input is generating a significant return on that investment.

Innovation: Costs and Benefits from Research Investment

Higher Education Institutes

The UK has placed the science and engineering carried out at its HEI's at the heart of its innovation policy. Because of this, there is a range of data available by which to assess their performance in delivering innovation and growth to the economy. In 2008/09 research grants and contracts for the HEIs, from BIS Research Councils, the Royal Society, British Academy and the Royal Society of Edinburgh was valued at £1,531 million (representing a total of 37% of all HEI research grants and contracts). In total, £4,144 million was available from all sources for UK research to be carried out at the 160 UK HEIs in 2008/09.

Higher Education-Business and Community Interaction Survey (HE-BCI) (HESA 2010, p. 33-37)

HESA (HESA 2010) statistics show that £732 million of research grants and contracts were allocated specifically for collaborative research between non-academic partners and the 160 Higher Education Institutes (HEIs) in 2008/09. Of this, £274 m (37.4%) came from the Department of Business, Innovation and Skills (BIS) Research Councils, £190 million (26.0%) from other UK Government Departments; £214

Table 1.HEI Intellectual Property Exploitation 2008-09
Source: Table Xi - Intellectual property (IP) 2008/09 and 2007/08; p 35 HESA 2010.

	2008/09	2007/08
Disclosures and patents filed by or on behalf of the HEI		
Number of disclosures	3,822	3,594
Number of new patent applications filed in year	2,097	1,890
Number of patents granted in year	653	587
Cumulative patent portfolio	14,276	13,968
Licence numbers		
Non-software licences granted	2,612	2,149
Software only licences granted	1,851	1,041
IP Income (£ thousands)		
Income from SMEs	12,388	11,610
Other (non-SME) commercial businesses	35,743	26,252
Income from other non-commercial organisations	8,352	6,654
Subtotal IP Income (£ thousands)	**56,483**	**44,516**
Sale of shares in spin-offs	67,885	21,197
Total IP revenues (£ thousands)	**124,368**	**65,713**
Total Costs (£ thousands)	**27,794**	**22,794**

million (29.2%) from EU Government and £54 million (7.4%) from other sources. Using this subset of the UK HEI research investment (rather than the total £4 billion above), the innovation outputs as measured by patents, licencing agreements, IP income and number of spin-off companies were reviewed.

The cumulative patent portfolio of the UK HEIs increased from 13,968 in 2007/08 to 14,276 in 2008/09; a total number of 587 and 653 patents were granted and 1,890 and 2,097 new patent applications filed in these respective years (Table 1.). A total of £56 million income was generated from IP with a further £68 million from the sale of shares in spin-off companies (HESA 2010). The bulk of the IP income £36 million, was generated by established, non-SME commercial businesses, hence although the SME sector is utilising university expertise (£12.4 million of income from SMEs), the major source of IP productivity is from larger companies and multinationals who make up less than 5% of UK companies (HESA 2010).

In 2008/09 there were 1,077 active firms that were spin-offs with some HEI ownership, 243 formal spin-offs, 248 staff start-ups, and 3,993 graduate start-ups (Table 2.). In this one year, 157 new spin-offs were created and 34 formal spin-offs. Graduate start-ups reached 2,031 for the year and there were 53 staff start-ups created. In addition, there were 2,097 patent applications filed with an average total number of 90 patents held per HEI, and on average in 2008/09 four new patents were granted and 13 new patents filed per institution. In 2008/09 on average there were seven active spin-off companies with some HEI ownership per HEI, along with (on average) one new spin-off created per year per institute (HESA 2010).

This means that for an annual investment of £732 million of research funding for HEIs in 2008/09 a return of £56 million was generated from intellectual property (IP), each spin off company cost on average £3.8 million to establish and generated £290K in IP income, while each patent application filed cost on average £349K. In addition, a recent report by BioCity Nottingham and Mobius demonstrated that only one third (34%) of life science companies set up in the UK originated as University spin-offs and of those that did, on average had a research cost of £38 million to establish (assuming 4* world leading researchers at full economic costs - and higher than £38 million if research is lower quality).

Another way of defining the metrics is to consider that the 53 staff start-ups for 2008/9 were created from the endeavours of 139,784 FTE academic professional staff in the UK's HEI, which equates to less than 0.04% of the academic population generating spin-offs. If it is assumed that each patent application is made by

Table 2. HEI Spin-off Company Activities 2007-09
(Source: Table Xii - Intellectual Property (IP) - spin-off activities 2008-09. p 36. HESA 2010)

	Number	No. still active which have survived at least 3 yrs	Number of Active Firms	Estimated current employment of all active firms (FTEs)
2008/09				
*Spin-off with some HEI ownership	157	820	1077	11,322
**Formal spin-offs, not HEI owned	34	160	243	3,026
***Staff start-ups	53	164	248	1,062
****Graduate start-ups	2,031	1,657	3,991	7,917
2007/08				
Spin-off with some HEI ownership	168	789	1,098	10,735
Formal spin-offs, not HEI owned	54	132	224	3,350
Staff start-ups	38	153	240	2,351
Graduate start-ups	1,924	1,273	3,829	6,167

**Spin-offs with some HEI ownership are companies set up to exploit IP that has originated from within the HEI where the HEI continues to have some ownership. ** Formal spin-offs, not HEI owned are companies set-up based on IP that has originated from within the HEI but which the HEI has released ownership (usually through the sale of shares and/or IP). ***Staff start-ups are companies set up by active (or recent) HEI staff but not based on IP from the institution. ****Graduate start-ups include all new businesses started by recent graduates (within two years) regardless of where any IP resides, but only where there has been formal business/enterprise support from the HEI.*

Table 3. BBSRC Grant-in-aid 2005-09 (Source: Table 2i: BBSRC grant-in-aid in Economic Impact Reporting Framework 2008/09)

2005/06	£321.8m
2006/07	£365.8m
2007/08	£393.7m
2008/09	£407.5m

Total grant-in-aid 2005-09 = £1,488.8m; 2005-08 = £1,081.3 m.

Table 4. BBSRC-sponsored institutes, license income 2005-09 (Source: Table 5xi:BBSRC-sponsored institutes, license income Economic Impact Reporting Framework 2008/09)

2005/06	£700K
2006/07	£800K
2007/08	£700K
2008/09	£700K

Total license income 2005-09 = £2.9m

Table 5. BBSRC University commercialisation activities 2005-08 (Source: Table 5xx: BBSRC University commercialisation activities Economic Impact Reporting Framework 2008/09)

	2005/06	2006/07	2007/08
Number of departments	15	13	12
BBSRC Funding	£39.7m	£36.1m	£39.8m
Exploitation income	£1.9m	£0.8m	£4.5m
Spin-out companies	38	37	22

Total University BBSRC funding 2005-09 = £115.6m
Total Exploitation Income 2005-09 = £7.2m
Total number of spin-out companies = 97

Table 6. BBSRC-sponsored institutes, spin-out companies 2005-09 (Source:Table 5xxii: BBSRC-sponsored institutes, spin-out companies, BBSRC Economic Impact Reporting Framework 2008/09)

	2005/06	2006/07	2007/08	2008/09
Number of companies incorporated	1		5	
Number of trading companies	16	17	17	16
Number of dormant companies	7	5	11	7
Number of staff employed in trading companies	92	104	134	134

a single individual and there were 2,097 applications filed in 2008/09 this would mean that only 1.5% of HEI staff were involved in research that could be patented that year - figures for other years do not brighten the picture. If it is assumed that number of start-ups and patents are surrogate indicators of potential commercial research outcomes then the picture does not look particularly good.

HEI's have a tremendous depth of scientific expertise. However, making such institutions the focus for driving innovation when their primary function is education and the generation knowledge may be misguided (Dent 2010). The limitations of HEI research for innovation with respect to business have increasingly become apparent. In Connell and Proberts (2010) analysis, firms were critical of the slow pace of university research and the tendency to overstate market readiness, and hence the value of its IP. It is also not uncommon for an HEI developed high performance technology to find no market. This issues was highlighted in the study of Morgan Cole (2006) which identified lack of market as one of the key factors affecting spin-off success for HEIs. The report on Life Science companies by the BioCity Nottingham and Mobius (2010) noted that even though HEI's were apparently responding to the need to produce innovative spin-off companies that, many of those listed on university websites appeared to be companies in name only. It is also pertinent to note that, although failure rates of HEI spin-offs are relatively low, where this occurs it is often down to the technology not living up to expectations, and/or a lack of market for the technology and the subsequent problem of running out of funds (Morgan Cole 2006). Understanding the business markets is an area in which HEI's tend to have little expertise relative to business, yet to innovate effectively it is essential to understand the market.

BBSRC Sponsored Institutes

The year on year breakdown of BBSRCs total grant-in-aid of £1,488 million for the period 2005-09 is given in Table 3. In 2008/09 the BBSRC Core Strategic Grants to its institutes was £56,326 million with an additional £6,842 million provided as Research Initiative funding and £12,145 million as Responsive Research Grants (BBSRC Annual Report and Accounts 2008-2009). Over the period 2005-09 the BBSRC sponsored institutes generated £2.9m in license income (Table 4.), 16 trading companies, (Table 6), 98 licensing agreements with UK companies (Table 7.), 255 breeders rights agreements and patents that generated an income (Table 7.), a total IP exploitation income of £6.2m from IP which cost £1.9m to protect (Table 7.); while from

Table 7. BBSRC-sponsored institutes, exploitation data 2005-09 (Source: Table 5xx1: BBSRC-sponsored institutes, exploitation data Economic Impact Reporting Framework 2008/09)	2005/06	2006/07	2007/08	2008/09	*Total
Number of patents and plant breeders rights held by institute	126	136	140	83	485
Number of current licensing agreements	37	41	53	36	167
Royalty income	£400K	£600K	£500K	£600K	£2.1m
Number of patents and plant breeders rights held by collaborators	15	14	16	27	72
Number of current licensing agreements	8	7	7	11	33
Royalty income	£200K	200K	£300K	£100K	£800K
Number of patents and plant breeders rights which generated income	76	78	82	19	255
Number of licensing agreements involving companies with significant research or manufacturing capacity in the UK	26	23	36	13	98
Income from sale of equity in start-up companies	£400K	£500K			£900K
Income from any other exploitation of research	£600K	£700K	£600K	£600K	£2.5m
Total exploitation income	£1.7 m	£2.0m	£1.3m	£1.3m	£6.3m
Total cost associated with IP protection	£500K	£500K	£400K	£500K	£1.9m
Number of employees involved in commercialisation activities	9.5	9.8	10.6	7.2	37.1

**Totals not provided in original source tables*

BBSRC HEI sponsored commercialisation activities valued at £115 million, the investment generated £7.2 million in exploitation income and 97 spin-out companies over the period of 2005-08 (Table 5).

Given these figures, and by any normal business or investment criteria, the returns generated on the investment fall far short of that required to justify their cost. Although it is recognised that the institutes and activities of the HEI's add value in additional ways to the figures presented here, such large investments for such small 'commercial' returns in terms of short term economic impact must surely call in to question the validity of this science–led investment strategy.

Emphasis on science-supply and technology development

Traditionally science and engineering have been associated with innovation through their ability as disciplines to generate new technologies. Table 8 demonstrates how when university expertise is categorised by cost centres the science, medical and engineering disciplines all generate substantially more external income to cover staff costs than the social, business, humanities and arts subjects, reflecting the investment that is being in R&D in these subjects. The research councils spend is given in Table 9. and shows a similar trend.

Excluding facilities (which are largely associated with large national and international scientific projects), the total funding available for conventional science, medical and engineering R&D is £2,457 million compared with £287 million (10.5% of the total research funding) in arts and humanities. Such funding does not reflect the total research that is conducted by social sciences, humanities and arts, because a great deal of research in these subjects can be conducted with access to a good library and individual endeavour. What is implied however, is that we are prioritising R&D approaches to innovation that emphasise 'traditional' science and technology, which as a consequence must limit the type of innovation likely to be derived from the UK research base.

Improving measures of input and output

The constraint faced in estimating the value of innovation is that we are unable to assess the success generated by a solution against an appropriate measure of the extent of an offered opportunity especially if a technology prevents a problem manifesting e.g. management of bluetongue disease.

If one proposes to write a scientific text-book however, an estimate of the market size for the book is integral to the assessment publishers make in determining whether to commission the work or not. If a market is not considered big enough then the book will not be commissioned irrespective of how good the book concept. The science-supply-led paradigm of innovation to which we adhere (Dent 2010)

Table 8. The percentage of UK HEI, organised by cost centres which is derived from non institutional sources of finance (competitive grants, commercial contracts etc) (Data derived from Table S. p.31 of HESA; Resources of Higher Education Research Institutes 2008/09.

Cost Centres	% salary derived from non - institutional sources
Medicine, dentistry and health	43.2
Agriculture, forestry and veterinary science	32.3
Biological, mathematical and physical science	45.1
Engineering and technology	30.9
Architecture and planning	11.0
Administrative, business and social studies	9.1
Humanities & language based studies & archaeology	9.9
Design, creative & performing arts	3.1
Education	7.5

Table 9. UK Research Council allocation of funding for 2009

Research Council	Spending 2009 (£millions)
Arts and Humanities	109
Economics and Social	178
Engineering & Physical Sciences	843
Non Clinical Biosciences	471
Medical	707
Natural Environment	436
Facilities	652

forgoes any assessment of the size of market prior to commissioning the research. It is argued that for a great deal of scientific research, especially that labelled "blue skies" it is impossible to predict what may come out of it that may be of economic value - the size of the market is unfathomable. In addition to this, others argue that because of the long time frames involved in realising some indirect benefits derived from scientific enquiry, no attempt should actually be made to measure economic impact. Attempts are being made however, to improve this situation through the Research Evaluation Framework (REF; 2014) of impact which includes under its categories of impact "Creating new businesses, improving the performance of existing businesses, or commercialising new products or processes" with associated indicators:

- research contracts and income from industry
- collaborative research with industry (for example measured through numbers of co-authored outputs)
- income from intellectual property
- increased turnover/reduced costs for particular business/industry
- success measures for new product/services (for example growth in revenue)
- success measures for spin-out companies (for example, growth in revenue or numbers of employees)
- patents granted/licences awarded and brought to market
- staff movement between academia and industry

On the assumption that these metrics are accepted and adopted for the framework in 2014 then they will certainly allow a positive step forward in better measurement of successful business outcomes. However, without appropriate baseline measures of the nature and extent of the market opportunity for which science, engineering and technology is seeking a solution, it will always be difficult to make an informed assessment of economic impact.

One way to address this would be to obtain more information about the size and scope of the market sector that is relevant to the science being undertaken and define through appropriate metrics the scale and parameters of market gaps and opportunities for which solutions are sought. Such metrics might be based on the number of businesses, patents, registered designs, types of technology and service within a particular sector, with numbers of the gaps and opportunities defined in terms of patent space, conventional product market size, business models, processes and supply chain needs. Against such metrics it becomes possible to determine how many, and to what extent, they have been addressed through investment in research creating new technologies, products, services including business start-ups, new business models, availability and value of processes and improved efficiency of supply chains. If the market becomes the starting point for innovation then such market metrics become possible, and can be measured against the investment that generates the solution.

Terminology

Market: the traditional view of the "market" is that it the term refers to the group of consumers or organisations that is interested in a particular product or service and have the resources to pay for it. The use of the word market in the context of this report is wider than a consumer focus and is defined by the range of business types, business models and processes, products and services, information needs, technology use, attitudes to innovation as well as consumer needs, trends and demands operating within the sector.

Market Research: the process by which to identify the nature of businesses in a particular sector, their technology and process needs, opportunities and gaps in the business models, products, services and processes used, organisational needs, as well as customer needs and demand

Spin-offs: the term 'spin-off company' is used throughout and is considered synonymous with the term 'spin-out company'

Market-led and science supply-led: the terms science supply-led and market-led are used deliberately throughout the report as opposed to more commonly used terms science push and market pull because push and pull and science-led and market-led mean different things. When people talk about market demand and market pull they think of there being an identified market with the consumer need pulling through a new product or service. In actual fact most radical inventions are not market pull or demanded by the consumer - no one asked for CDs or personal computers - these were market opportunity and market gap led - there was no initial demand. The term 'led' emphasises the driver not the output - so market-led, market demand and market pull are used in specific ways rather than any generic sense, throughout the report.

Abbreviations and Acronyms

BBSRC	Biotechnology and Biological Sciences Research Council
BIS	Department for Business, Innovation and Skills
CST	Council of Science and Technology
DTI	Department of Trade and Industry (forerunner of BIS)
EEDA	East of England Development Agency
FTE	Full Time Equivalent
HE-BCI	Higher Education Business and Community Interaction Survey
HEI	Higher Education Institute
HEIF	Higher Education Innovation Fund
HESA	Higher Education Statistics Agency
IP	Intellectual Property
KTN	Knowledge Transfer Network
MIC	Market Innovation Centre
MP	Member of Parliament
OECD	Organisation Economic Co-operation and Development
PIN	Personal Identification Number
R&D	Research and Development
REF	Research Evaluation Framework
SME	Small to Medium Enterprise
TIC	Technology Innovation Centre
TRIZ	Teoriya Resheniya Izobretatelskikh Zadatch
TSB	Technology Strategy Board
TTO	Technology Transfer Office
UKTI	UK Trade and Investment, Department Business, Innovation & Skills

Author Profiles

Dr David Dent

David's career encompasses academia, international institute research, management and leadership; establishing, securing funding and working in spin-off and start-up companies, inventing, patenting and licensing product, business model and process innovations; and business consultancy. Having worked in over 30 countries, been the former Managing Director of CABI Bioscience, he is currently a Vice President of the Parliamentary and Scientific Committee and Public Governor of the Surrey and Borders NHS Partnership Trust, as well as a Director of Dent Associates Ltd and ADG Publishing Ltd. Of recent note is his role as Founder of the Pennies Foundation having conceived of the idea, David proved the technical feasibility of rounding-up to the nearest pound point of sale transactions using credit and debit cards, secured a business process patent, assembled the team, engaged stakeholders (banks, retailers, card industry, charities, government) as well as securing the first phase of funding and engaging his successor. The Pennies Foundation and card payment rounding-up process - now known as the Electronic Money Box, is set to transform charitable fundraising.

Professor Mike Theodorou

Mike has had a successful career in applied research as an anaerobic microbiologist involving, scientific research management, institute level management and leadership, patenting and commercialisation of technology, technical inputs to science based business as well providing expert advice to government. The former Head of the Plant, Animal and Microbial Science Department at the Institute of Grassland and Environment Research, Aberystwyth and Head of Science Development at Aberystwyth University, Mike is currently the Centre for Process Innovation Chair in Industrial Biotechnology at Durham University. Mike is Technical Director with Biosource (Wales) Ltd; a research and development company specialising in the exploitation of continuous technologies for microbial cell growth and plant biomass digestion processes - converting organic waste and biomass into biofuels. Mike has recently developed a new, patented process for continuous anaerobic processing.