Department for Business Innovation & Skills

OUR PLAN FOR GROWTH: SCIENCE AND INNOVATION

Evidence Paper

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Foreword

Research and innovation are essential for sustainable economic growth and addressing grand challenges. There is compelling evidence that research and innovation generate large and lasting returns for the economy. This report summarises what the evidence tells us about what drives successful research and innovation systems, what impacts they have, and how we can benchmark the UK's performance.

A clear theme that runs through this report is the need for all components of the system to work seamlessly together. Effective collaboration is key, including between the public, university and business sectors, but also across national boundaries. The UK is currently at the heart of the global research and innovation system. In order to have a successful and prosperous economy in the future, it needs to remain there, even as the scale and pace of research activity increases across the world.

Another theme is about learning from experience and putting that learning into practice. This is why it is important that a Science and Innovation Strategy is based on careful consideration of the evidence, and why this report is important.

Finally, by setting out what we do know, we make it clearer what we still don't know. There is better evidence on the role and impact of research and innovation than ever before, but gaps remain. It is important that we continue to do all we can to understand how the science and innovation system operates in order that the economy and wider society can reap the maximum benefits..

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Introduction

The various elements, actors and sub-systems in the UK science and innovation system are **highly interdependent, multi-faceted and interconnected** and extend well beyond our national borders. With this complexity comes increasing demands that we understand the workings of the system to ensure effective evidence-based policy-making. Our understanding has progressed significantly in recent years.

We understand better than ever before how science, innovation and business are constantly evolving, and the value this generates for our economy. We now know that more open systems are associated with greater positive impacts on society and over the last fifty years, we have steered our research and innovation system from a knowledge-transfer and institution-focussed approach to an open and collaborative system with the government, partner organisations and individual citizens as integral partners. **The UK is central to the global science and innovation network**, with the outputs of our knowledge base and the impacts of our policies cutting across national, institutional and technological boundaries. Our institutions contribute to and draw upon a rich international knowledge base, collaborating with government, entrepreneurs and industrial partners to share in the risks and the rewards of their investment.

However, **the global scale and pace of research and innovation is increasing**. This presents huge opportunity for the UK. However, a strong interconnected knowledge and innovation base needs to attract foreign investment and the brightest talent from abroad. Continuing to attract such talent will require continued investment in our knowledge base so that it equals the best in the world.

While the fundamental economics of science and innovation and their centrality to growth have been recognised since the 1940s; advanced economies are increasingly recognising the investment potential of their knowledge base and making it a core component of their plans for growth. The UK, as with many OECD countries, now invests more in knowledge and intangible assets, which have displayed strong resilience to the economic downturn. Despite the uncertainty and the long lag between investment and payoff, there is a strong body of evidence suggesting that **public investment in our science and innovations system delivers average social returns of between 20 per cent and 50 per cent a year**, with benefits lasting over decades.

In addition to the system and its impact at the national-level, we are increasingly developing insight into the mechanisms at individual firm and institutional level. We know that firms which persistently invest in research perform better than their non-innovative counterparts and are **more resilient in the long term**.

However, a successful science and innovation system means business, academia and other partners working together to solve common challenges. We know that **public support for science and innovation crowds-in private investment**. We also know that the complexity of the system and the nature of knowledge mean that market and system failures are pervasive. Government plays a key role not just in overcoming market failures but shaping new markets, and in harnessing the true potential of the system to build the necessary skills for research and innovation and to generate economic growth.

The role of the knowledge system

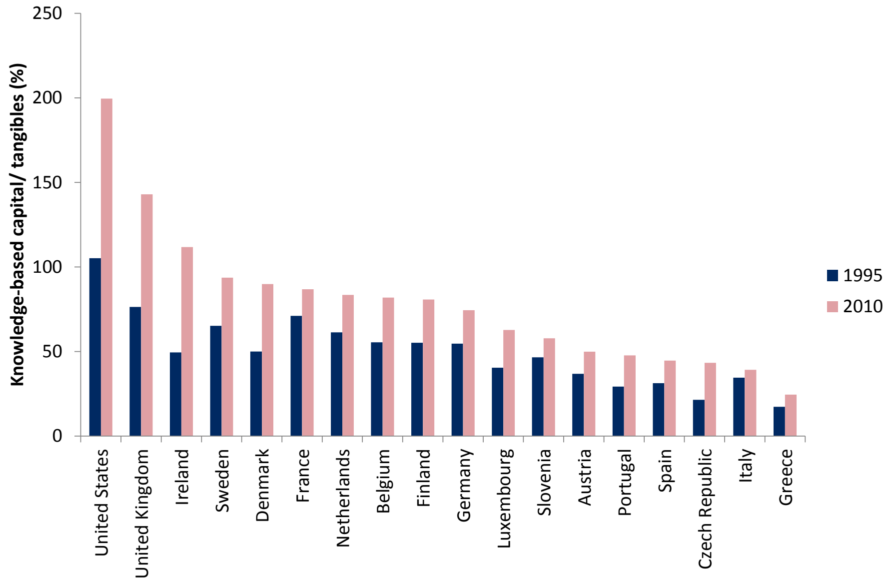
Science and innovation are crucial for the economy and wider society. Effective use of knowledge improves the way we use resources, creates new markets and ultimately enhances our lives. The benefits from investment in knowledge are overwhelmingly positive and need to underpin any developed economy's strategy for growth.

Knowledge is the source of long-term growth and a better quality of life

Since the early economic growth theories of Schumpeter[1], Solow and Swan, our understanding of where ideas originate and the processes by which they lead to economic outcomes has seen a number of advances. We have moved on from seeing the expansion of knowledge as a series of random events outside our control, to now incorporating knowledge-creation as an important investment criterion for businesses, universities and governments. Our understanding of how firm-level competition drives innovative behaviours[2]; the importance of skills[3] and connections between different parts of the system; and the contribution they make to economic growth has progressed significantly in recent years[4]. Indeed the need for knowledge and innovation policy to become more central to growth policy is reflected through the Government's Industrial Strategy, which provides support for all sectors to help increase global competitiveness, support innovation and maximise export potential.

There is general agreement that while short-term bursts of economic growth may be achieved through increases in the physical capital stock, long-term sustainable growth, particularly in developed economies, rests ultimately on expanding the frontiers of knowledge alongside our physical capabilities. Investments that build on our stock of knowledge comprise a range of assets which create future benefits for firms and, unlike machines, equipment, vehicles and structures, are not tangible. The Office for National Statistics, in alignment with the new European System of Accounts (ESA), has recognised the important contribution that knowledge-based investment make towards the capital stock, noting that the "*change in treatment of Department for Business, Innovation and Skills (2014) [research and development] from intermediate consumption to investment in intangible assets is one of the most significant changes made in ESA 2010*"[5]. They are growth promoting as they generate spillover benefits[6] and once created, can be used or reproduced at little or no marginal cost. This leads to increasing returns to scale in production[7], a property that makes ideas and knowledge an engine of growth. Scale economies of this sort can be reinforced by positive network externalities particularly in the digital economy sector where the benefits rises with the number of users, as illustrated by Linux android operating system. For these reasons, **knowledge-based capital is a key driver of economic growth in advanced economies** (Figure 1) and increasingly the largest form of business investment[8]. Indeed, the OECD describes economies, which display a trend towards greater dependence on knowledge, information and high-level skills, as knowledge-based economies[9,10].

Figure 1: Growth in knowledge-based capital across developed economies

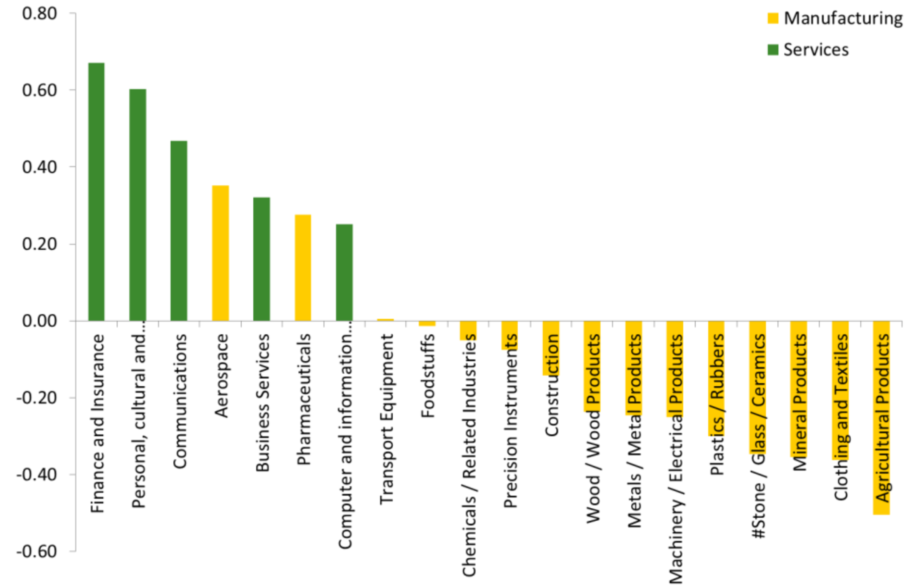


Source: Carol C., Haskel J., Jona-Lasinio C. and Iommi M., (2012), 'Intangible Capital and Growth in Advanced Economies: Measurement Methods and Comparative Results'. Working Paper, June. Available at http://www.intan-invest.net

The UK is one such economy. It cannot compete on the basis of cheap labour, proprietary capital or natural resources. Indeed, it is increasingly unlikely that any country will be able to build sustainable and long-term prosperity simply from these factors. **The UK must compete on the basis of its innovation capacity**, not least because its comparative advantage is disproportionately derived from R&D and innovation intensive sectors (Figure 2)[11]. These breakthroughs, which might be marginal improvements on established technologies or radical and disruptive novel approaches, are vital for the sustainability of the UK economy and vibrancy of the innovation system.

SMEs with a history of innovating are more likely to export, more likely to export successfully, and more likely to generate growth from exporting than non-innovating firms[12]. Yet currently just a quarter of UK Small and Medium Enterprises (SMEs) engage in export activities, and only 6 per cent export more than 50 per cent of their sales. There is significant untapped potential here; between 9 per cent and 12 per cent of non-exporting SMEs with employees are potential exporters[13]. Of those firms which export intermittently, between 54 per cent and 59 per cent could be converted to persistent exporters. The key distinguishing feature is participation in innovation activities.

Figure 2: UK revealed comparative advantage[i], 2013



Note: excluding category of pearls, precious stones, metals, coins, etc due to year-on-year volatility. Source: Updated analysis of Figure 1 in BIS (2014) 'Insights from international benchmarking of the UK science and innovation system' using Trademap data.

The evidence on the impact of knowledge-based investment on economic growth points overwhelmingly towards significant and positive returns. It is estimated that total factor productivity (a measure of technological change) accounted for 69 per cent of UK economic growth between 1960 and 2000[14]; with capital-deepening accounting for the remaining 31 per cent. Further, 51 per cent of productivity growth between 2000 and 2008 was due to innovation (including the impact of technological change and intangible investment), with 32 per cent attributable to changes in technology resulting from science and innovation[15]. There is also clear evidence that investment in science and innovation yields high returns; **private rates of return to R&D investment are estimated to be of the order of 20 to 30 per cent, with social rates of return two to three times larger**[16,25] **(Figure 3)**. However, not all research and innovation activity should be motivated by an economic outcome alone, as **a focus on purely economic returns significantly understates the true value to society of investing in science, innovation and skills**[17].

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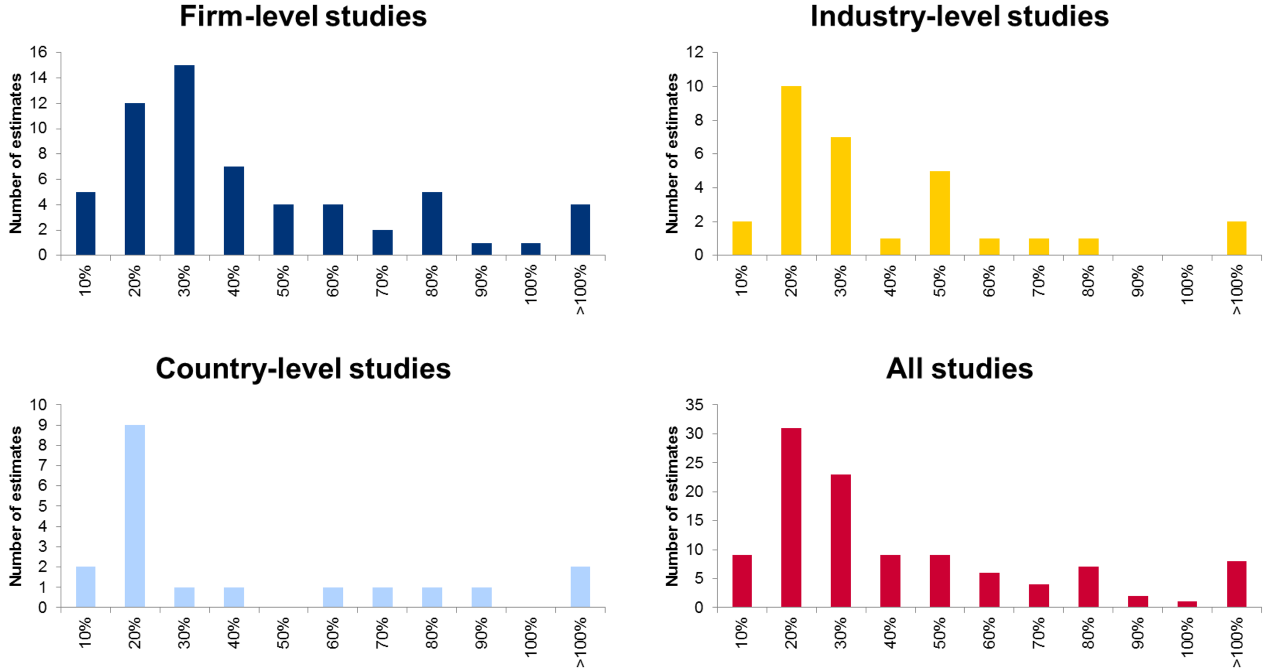
[i] A positive relative comparative advantage (RCA) value indicates that compared to the rest of the world, a sector represents a disproportionately large share of a country's overall exports; 1 would imply a country is completely specialised in a specific sector; -1 that the country has no exports in that sector; and 0 that the share of the sector in the country's exports is exactly the same as the world share of that sector.

Figure 3: Estimated private rates of return to R&D investments, by unit of analysis



Source: Frontier Economics (2014). 'Rates of return to investment in science and innovation'.

Table 1: Ratio of social to private rates of return to R&D where both estimated

Level of analysis	No. papers	No. estimates	Min ratio	Max ratio	Median	Mean*
Firm	1	4	1.4	2.1	1.8	1.8
Industry	11	15	1.0	8.1	2.4	2.9
Country	3	3	1.3	1.6	1.3	1.4

Note: Frontier Economics analysis based on Hall et al (2009)

Investment in knowledge requires patience and determination

The UK public overwhelmingly see science[18] and innovation[19] as beneficial and understand that the allocation of resources to the pursuit of knowledge is the only way to unlock the solutions which will make their lives, and future generation's lives, easier. However, such **improvements take time** and while there are some immediate gains to be made through the development of high-level skills and absorptive capacity, economic returns require sustained investment, sometimes well beyond the lifetime of a parliament.

The search for solutions to major economic and social challenges is not a linear deterministic procedure; instead it is a risky[20], iterative process characterised by uncertainty and multiple feedback loops at every stage. For the science and innovation system to succeed in such an environment it needs certainty over its resources and policy must be designed to allow these feedback loops to happen[21], avoiding expectations of a simplistic linear progression from basic research to end product. Indeed, because of the path-dependence and firm-specific nature of absorptive capacity, a successful knowledge base requires persistent, rather than one-off, investment[22]. It may take a large number of attempts before a discovery is made; we cannot predict beforehand which projects will succeed. It is important therefore that policies do not rely on one understanding of the system, favour one sector, or back one technology; it is important to that policy does not stifle innovators from making those attempts. Although lags between investment and economic impact of one to three years are not uncommon, there is a large variation in estimates of lags for innovation expenditure; largely reflective of the high level of uncertainty inherent in undertaking research. While some estimates finds lags of up to 4 years[23], some survey evidence points to mean lags of between 6 and 7 years[24] and yet other evidence (particularly in the life sciences) suggest lags between 15 and 17 years[25].

Resources for the knowledge system

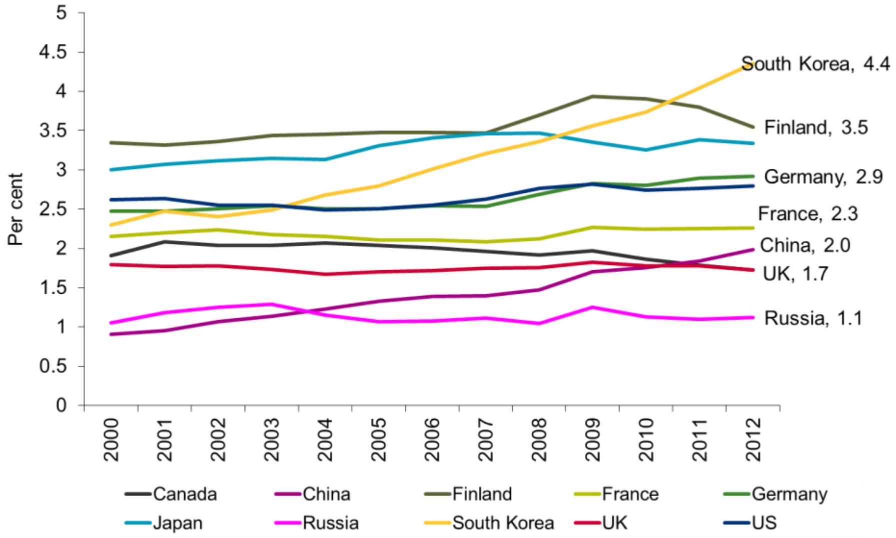
The UK needs a well functioning knowledge base if it is to successfully translate research success into real social and economic gains. To achieve this, the resources available for knowledge creation and dissemination must be sufficient, sustained and distributed effectively.

Investment remains below other leading nations

As global trade increases, and pressures from countries that compete on low costs rises, firms in developed economies are increasingly competing for high value-added activities in global value chains[26] and are turning to knowledge-based investments to drive sales growth. The latest survey of innovation in firms found that the proportion of innovation active firms has increased from 37 per cent in 2011 to 45 per cent in 2013, with the largest share of innovation expenditure accounted for by internal R&D[27].

In 2012, the UK was the seventh largest investor in R&D in the world, with 3 per cent of the overall global investment[28], amounting to £27bn[29]. However, overall R&D investment intensity in **the UK remains below other leading knowledge-based countries** and by some estimates may be sub-optimal for a developed country[30]. Gross expenditure on R&D in 2012 accounted for 1.72 per cent of GDP, down from 1.78 per cent the year before, and well below the average of other comparable nations[31]. In contrast, the US invests around 2.8 per cent of GDP on R&D per annum. China has been increasing its investment in its knowledge base; now investing at a higher intensity than the UK at 1.8 per cent of GDP. South Korea doubled, in real terms, its expenditure between 2005 and 2012, now investing 4.4 per cent of GDP. France and Germany have consistently invested substantially more than 2 per cent of their GDP in R&D, with Germany recently achieving its aspiration to increase this to 3 per cent of GDP. Other countries are increasing their expenditure rapidly too. South Africa, for example, has an ambition to increase R&D investment to 1.5% of GDP from a base of less than one per cent in 2009[32].

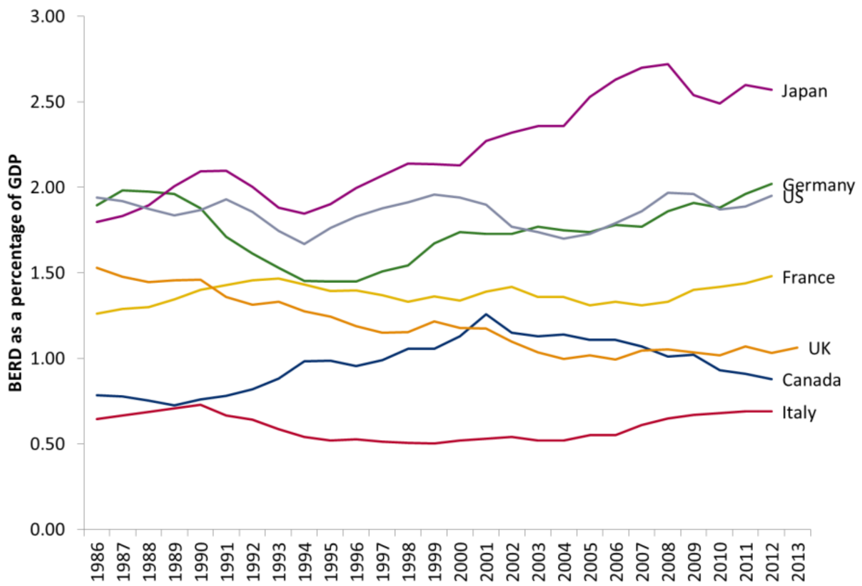
Figure 4: Gross expenditure on R&D as a share of GDP, 2000-2012



Source: OECD Main Science and Technology Indicators

UK business R&D, which accounts for approximately two-thirds of total R&D expenditure in the UK[33], did rise by 6 per cent in real terms (Figure 5) in 2013. It largely weathered the global financial crisis, remaining at approximately 1.1 per cent of GDP for most of the last decade[33]. Once industrial structure is accounted for, the UK intensity is closer to the OECD average, moving up from 71 per cent of the average to 92 per cent. However, there is still a “BERD gap” between the UK and the OECD average. The United States, France and Finland remain at least one percentage point higher than the UK[31].

Figure 5: Business expenditure on R&D as a share of GDP, G7, 1986-2013

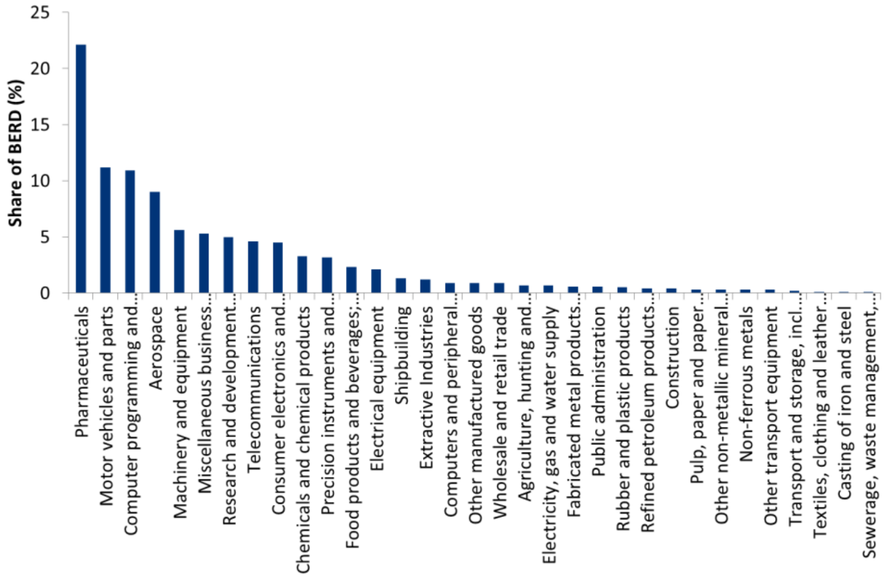


Source: OECD Main Science and Technology Indicators; Office for National Statistics (2014) ‘Business Enterprise Research and Development, 2013’

Nevertheless, the UK still has a lower R&D intensity than other R&D nations. While this is in part related to a comparatively low level of government investment in research it is partly due to the **strong concentration of business research investment along a number of dimensions.**

- **Heavy industrial concentration of research** –The R&D base is broadening (business R&D expenditure in the service sector increased 54 per cent between 2002 and 2013 in real terms; construction research increased 57 per cent; electricity, gas, water-supply and waste management R&D more than doubled; and research expenditure in the extractive industries was 281 per cent higher) but business R&D remains highly concentrated, with almost **two-thirds of R&D accounted for by just 6 of the 33 product groups** in 2013 and pharmaceuticals alone accounting for 22 per cent. There is clearly scope for under-represented sectors to play a greater role in the UK research base.

Figure 6: Business expenditure on R&D by product group, 2013



Source: Office for National Statistics (2014). 'Business Enterprise Research and Development, 2013'.

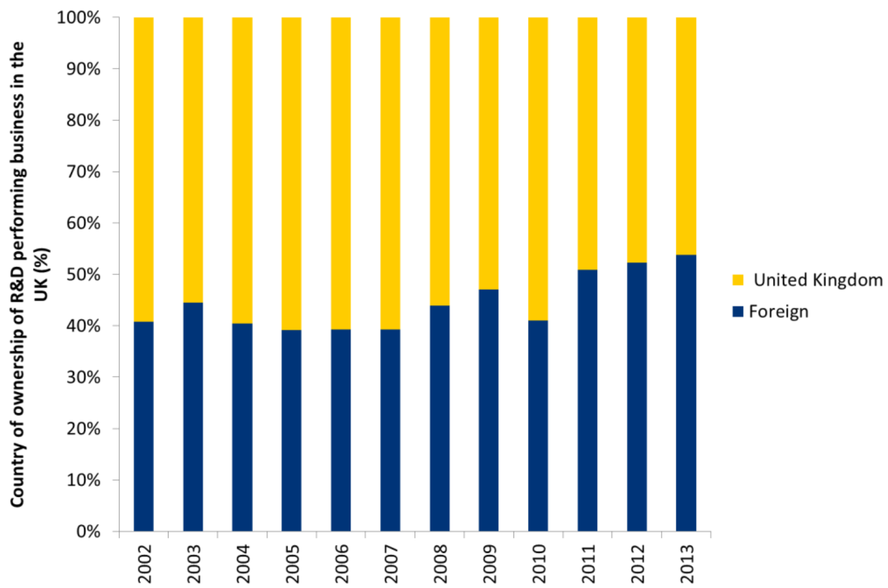
- **Poor innovation performance in SMEs** - The latest UK Innovation Survey found that in the period 2010-2012, **more than half of firms were not innovation active** and the most recent business R&D statistics show that over 50 per cent of business research expenditure took place in just 50 enterprise groups[ii]. While firms with less than 250 employees account for 99.6 per cent of businesses[34], they only account for about a fifth of business R&D expenditure and, if we exclude subsidiaries of larger organisations, this falls to only 4 per cent of R&D investment. Among G7 countries, only Canada and Italy have a lower business R&D as a share of GDP. The European Innovation Union Scoreboard identifies SME innovation performance as an area of weakness for the UK[35]

[ii] An Enterprise Group consists of all the enterprises under the control of the same owner. The Business Enterprise expenditure on R&D survey covers 400 enterprise groups. The top 50 enterprise groups accounted for 52 per cent of business R&D expenditure and 37 per cent of R&D employment (FTE).

and there is **clear potential for expansion of domestic business-led research activity** in this area.

- **Low R&D among UK-owned firms -** In 2011, the UK attracted almost $7 billion of overseas-financed R&D. This was the same as Canada, Finland, Japan, China, and Russia combined, more than either France or Germany ($4 billion each) and just under half that of the USA (with $16 billion)[28]. The quality of the research; the talented people who benefit from the UK research base; and the promise of significant positive returns are key drivers in attracting foreign investment into the UK [16 78 36 37] and in contrast to the experience in other countries, the UK has remained an attractive destination for foreign investment. For example, in the last 2 years the UK overtook Germany as the number one recipient of EU Framework Programme 7 funds[38]. However, with over a fifth of business R&D financed from abroad[iii] and the proportion of business R&D conducted by foreign-owned firms increasing significantly to exceed 50 per cent for the first time in 2011, there may be cause for concern that resilience in overall business expenditure masks an **underlying weakness among UK-owned firms**.

Figure 7: Business expenditure on R&D by country of ownership, 2002-2013



Source: Office for National Statistics (2014). 'Business Enterprise Research and Development, 2013'.

However, investment in **R&D is also understood to be only a small component of a growing body of knowledge-based capital**, which has been shown to drive labour productivity growth[39]. Indeed, where market sector investment in scientific R&D amounted to almost £16bn in 2011, investment in training which has more than doubled since 1990, amounted to over £33bn[8]; investment in computerised information and databases exceeds £24bn and design £15.5bn[8]. Between 2010 and 2011 the UK increased its investment in such 'intangibles' by £3 billion to £138 billion, compared with £90 billion investment in

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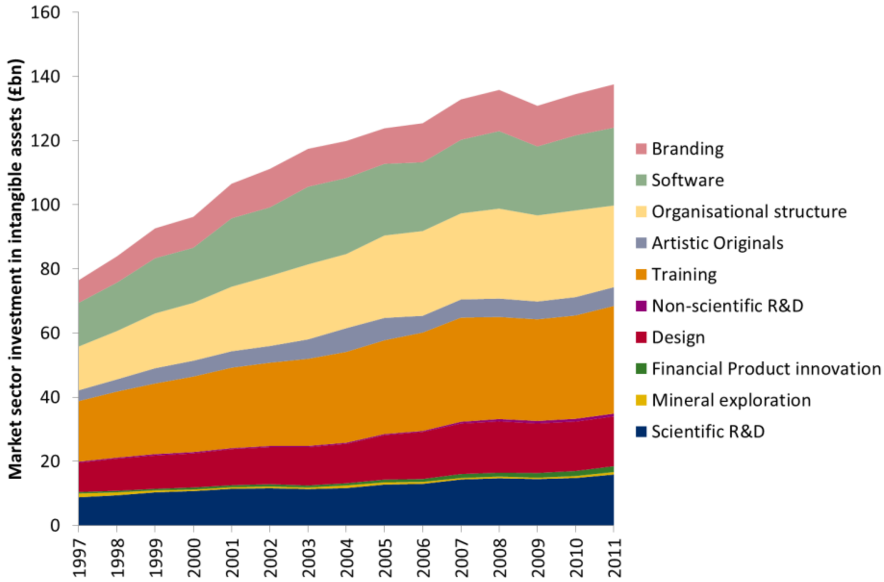
[iii] Overseas funding for UK business R&D dropped 7 per cent between 2008 and 2009, however, recovered to above pre-crisis levels from 2010 onwards.

tangible assets[8]. These investments range from R&D to design to organisational capital[iv], an area of particular strength in the UK, which accounted for £25.5bn market sector[v] investment in 2011.

Figure 8: Market sector investment in intangible assets, 1997-2011



Source: Goodridge, Haskel and Wallis (2014). 'UK investment in intangible assets'

The skills required for research and innovation are increasing

In addition to the financial resources allocated to the knowledge base, an important resource for, and output from, the knowledge system are the talented people who are empowered with the skills to transform our society. If firms are to recognise the value of new information, assimilate it and apply it for commercial purposes, it is vital that they have the necessary skills to complement their knowledge-based investment[40]. With 29 of the top 200 universities in the world[41]; 42 among the 100 most international universities[42] and 85 per cent of students expressing overall satisfaction with their course[43], the UK is well placed to ensure it has the future skills it needs to remain at the centre of global research and innovation. The UK is the fourth largest producer of doctoral graduates in the world[44]; and produces more science and engineering doctorates relative to population size than all comparator countries (except China, which produces large volumes of engineering doctoral graduates)[45].

Supply of skills

The UK has an above average proportion of the workforce equipped with the skills to face technology-rich environment[46], ranking in the top 5 for professionals in science and

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[iv] Organisational capital is an economic competency relating to the design of better and faster production processes and decision making.
[v] The market sector is defined as sections A-K, MN, & R,S,T according to the 2007 Standard Industrial Classification, thereby excluding Real Estate Activities (L), Public Administration & Defence (O), Education (P) and Health and Social Work (Q).

technology (as a share of total employment), and was above the EU average for percentage of entrants to tertiary education in engineering, science and health fields in 2012. However, the UK ranks 25th among OECD countries for the share of the workforce accounted for by technicians and associate professionals in science and technology[31]. **A sustainable supply of future talented skilled researchers and innovators requires an effective education pipeline** which equips students at all levels with the skills they need to tackle emerging challenges.

Through investment in the knowledge base and by building our national absorptive capacity, participation in research enhances the UK's ability to exploit knowledge generated both internally and internationally; **if a country cannot understand new ideas it cannot convert them into economic and social success**. In order to build and maintain the UK competitive advantage, it is important to possess: a diversity of knowledge[47]; the ability to draw on this knowledge in a productive manner[47]; the strong internal transmission structures which encourage and facilitates innovative behaviours[48]; and an openness to acquire and interpret externally generated knowledge[49]. Without this internal capacity, the UK would be poorly placed to respond to, and capitalise on, important breakthroughs achieved by our research partners elsewhere in the world.

Although the UK ranked 26th and 21st (out of 65 countries) for mathematics and science respectively in the 2012 international PISA results (relatively unchanged since the 2006 survey)[50], take-up of STEM-related subjects has increased over the long term. Take-up of the science component of the English Baccalaureate in state-funded schools has increased from 63 per cent in 2010 to almost 69 per cent in 2014[51]. Take-up of A-level physics, chemistry and biology has increased by 16 per cent, 17 per cent and 6 per cent respectively since 2010[52]. In 2008/9 there were 269,000 graduates in STEM-related disciplines. By 2012/13 this had risen to approximately 313,000 (or 40 per cent of the graduating population that year).

Importantly, these increases are coming from internal demand. The application rate for all English 18 year olds, for example, increased in 2014 to 35 per cent (the highest ever level), benefiting disadvantaged young people from whom the application rate has nearly doubled from 11 per cent in 2004 to 21 per cent in 2014. This demand from students has been accompanied by increased supply; university acceptances increased by 25,000 (or 5.5 per cent) between 2010 and 2014. Acceptances for students from the most disadvantaged backgrounds increased by 25,000 (or 17 per cent)[53]. As a result, total UK-domiciled first degree enrolments in STEM-related subjects at English HEIs (for all years between 2003/04 and 2012/13) have increased in Biological sciences (from 85,300 to 122,000), in Physical sciences (from 37,700 to 52,700) and in Mathematics (from 17,100 to 26,500)[54].

The UK also benefits from the best talent across the world. Indeed the value of UK HE exports were estimate to be worth over £14bn in 2008/09[55]. Data on the mobility of international students show that the UK attracts more students into tertiary education than any other country after the United States; from a market of 4.5 million international students, the UK accounts for a 12.6 per cent share[56]. 18 per cent of students enrolled in UK HEIs are non-UK domiciled, with 70 per cent of these originating outside the EU[57].

Increases in the volume of high-level and STEM-related skills are not sufficient. With nearly 100,000 female STEM graduates either unemployed or economically inactive in

2010[58], it is also important that the UK has sufficient diversity within skills pipeline. The accessibility of STEM careers needs to be as high for women as for men. At GCSE level, there were 162,300 entries for biological science, 159,400 for Chemistry, 157,800 for physics and 650,800 for mathematics in 2012/13; the balance between males and females at in all cases was broadly even. However, the balance between males and females shifts significantly at A-level. Of the 62,700 entries for biological sciences, 58 per cent were female, but of the 34,700 entries for physics, only 21 per cent were female[59] - almost unchanged for the last 20 years[60]. In 2012/13, 1.1 million learners of all ages participated in government funded further education at Level 3, three-quarters of which were female; and a further 53,000 learners participated at Level 4 and above[61] (65 per cent of which were female). Over 50 per cent of the graduates from STEM-related disciplines in 2012/13 were female, albeit the overall balance masks significant imbalances within certain fields: for example, only 17 per cent of engineering and technology graduates were female[62].

Beyond undergraduate study, employers see postgraduate skills as having a major impact on business and one in five see doctoral graduates as 'business critical'[63]. Despite the prospect of higher earnings in the future (those with a postgraduate degree earn a premium of over 9 per cent[64,65]) nearly three quarters of postgraduate taught students have no financial backing and so must finance their studies themselves or via a bank loan. Where such degrees are a requirement for doctoral degrees this represents a potential constraint on the future diversity of the UK research base[66].

Demand for skills

A highly educated workforce, equipped with the science, technology, engineering and mathematics (STEM), management and entrepreneurial skills is crucial in determining businesses' effectiveness at recognising the value of new information and their ability to act upon that knowledge[11]. Analysis of the various avenues through which UK academics deliver impact have shown that commercialisation-based activities are a small component of the full system[67], and there is evidence that the pathways to impact most valued by the private sector are those activities which are oriented around people and building their skills[68]. Indeed **the value of investment in science and innovation is realised primarily through "*the production of trained graduates and post-graduates who have the ability to solve complex technical problems and network more effectively*"**[3].

It is estimated that demand for high-level skills will rise in coming years with an additional 2 million jobs projected by 2022 (further exacerbated by an increasingly ageing workforce), **and the share of employment in almost all occupations shifting in favour of higher level qualifications**; by 2022 it is estimated that more than 50 per cent of employed people will have qualification level QCF 4 or above (as compared to approximately 29 per cent in 2002) [69]. Already, the most frequently reported destination for PhD leavers is consistently employment, with most entering the Higher Education or private sectors providing a direct path to economic impact. For PhD leavers in 2011/12 who were supported by the Research Councils, approximately 48 per cent found employment in the HE sector becoming inputs into the science and research system as researchers[70]. It is also estimated that expansion in demand for high level skills will be accompanied by a change in occupational structure, with the share of total employment from Standard Occupational Classification codes 1, 2 and 3 rising from 42 per cent to 46 per cent over the decade 2012-2022[69].

STEM skills are particularly valued across the economy, with between a third and a half of STEM graduates being employed in a non-STEM-related job[71]. **Highly innovative firms have a significantly higher share of employment accounted for by science and engineering graduates**[3], even in sectors which are not traditionally associated with these disciplines. Similarly, the lack of STEM graduate employment in less innovative firms is particularly striking: the median number of STEM graduates employed by less innovative firms is zero. This in turn has a large positive influence on their propensity to invest in research; their use of external knowledge; how much they collaborate; and the likelihood that they introduce new-to-market products.

Skills shortages

While the supply of STEM graduates and technicians is increasing, demand from employers and career opportunities are broad[72]; leakage into non-STEM jobs is a significant factor, and creates uncertainty in assessing the balance between supply and demand. Current projections of supply of and demand for STEM skills do not account for all economic scenarios or potential increases in demand if the government's Industrial Strategy, or economic rebalancing, leads to increased economic growth in high-skill or technology-intensive sectors. Nevertheless, some analysis suggests that, on current trends the UK faces a shortage of key STEM skills in the future[73, 74] and further regional analysis suggests such shortages may be most acutely experienced in the South East of England and Scotland[75]. While analysis by the UK Commission for Employment and Skills suggested no overall shortages for STEM graduates, once migration, people working longer and changes in activity rates was accounted for, it flagged the sensitivity to changes in demand from the economy; a 5 per cent increase in the size of core STEM demand could lead to a shortage of 200,000 in the UK by 2020. Furthermore, analysis by the Institute for Public Policy Research suggests that demand will not only be for graduates but also for mid-level technical skills. They forecast net demand for science, research, engineering and technology professionals and associate professionals to exceed 1.1 million by 2022[76].

Performance of the knowledge system

The UK is one of the world's leading nations in science and research, delivering internationally competitive research and producing the skills we need to create an agile and responsive workforce. Our ability to act on this research excellence and translate this into economic success has improved significantly, placing us among the best in the world.

The UK benefits from a broad research capability

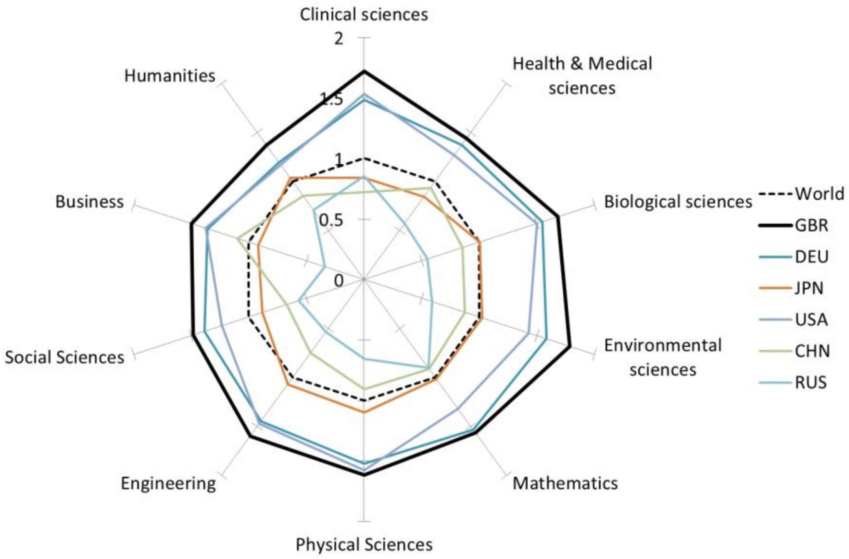
The UK research institutions are ranked among the best in the world[77]. The UK research base, plays a fundamental role in generating the advancements in knowledge which ultimately lead to social and economic gains. Through these public sector establishments, third sector research institutions[vi] and private sector research organisations, the UK produces knowledge outputs which, just like talented people and physical capital, can be brought together in innumerable ways to benefit the UK in the long term.

In order to do this, it is important for the UK to have a vibrant mix of talents and a broad capability in a range of areas for a number of reasons. First, international evidence shows that those countries which perform best at innovation tend to have balanced performance across a range of system metrics[35]. Second, a balanced portfolio helps to develop resilience and responsiveness within the system by mitigating the risk of over-reliance on a small number of specialisms, while building the absorptive capability to respond to new challenges and opportunities. Third, evidence has shown that having greater economic complexity, achieved through a diverse set of competencies, increases productivity and moves a country up the value chains[47].

In this endeavour **the UK research base punches well above its weight on the global stage**; with less than one per cent of the global population and only four per cent of the world's researchers, the UK accounts for 10 per cent of downloads, 12 per cent of citations and 16 per cent of the world's most highly-cited articles (second only to the United States)[78]. In contrast to countries such as China or Russia, where research impact is concentrated in a few fields (engineering, physical- and medical-sciences in particular) the UK maintains **a well-rounded research base** across a range of major research fields and multidisciplinary competencies (Figure 9). The UK is also positioned among the most productive research bases in the world. In 2012, the UK produced more articles and more citations per unit of expenditure than any other country in the G8 and was in the top three among comparator countries for articles and citations per researcher.

[vi] Charities are another major contributor to UK research. For example, non-profit institutions contribute £1.3billion funding in the health research sector. http://www.amrc.org.uk/our-members/sector-data

Figure 9: Field-weighted citation impact, 2012



Source: Elsevier (2013). 'International Comparative Performance of the UK Research Base – 2013'

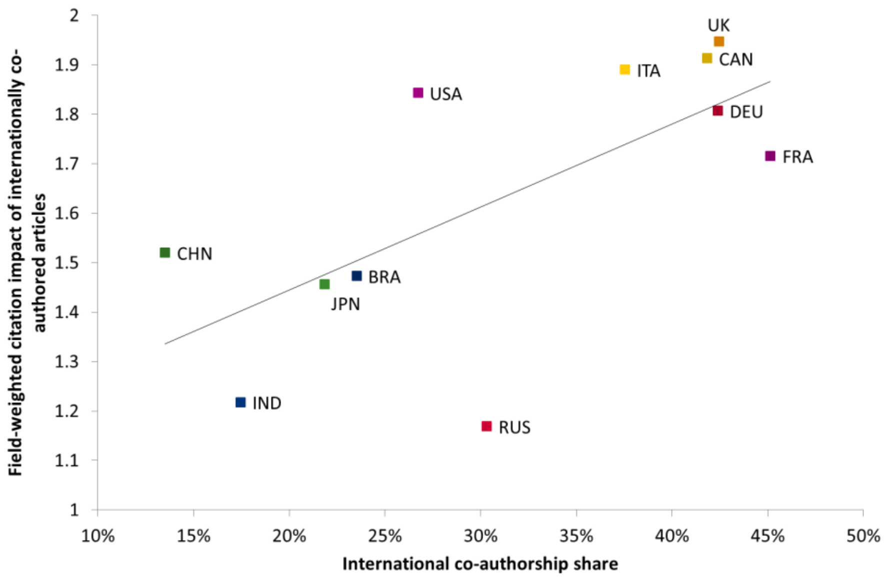
Not only is the UK active and highly productive in all major research fields, but when we account for the research quality, the UK ranks **best in the world on field-weighted citation impact**[vii] and scores more than 50 per cent higher than the world average in most fields. As a result, the UK has become a partner of choice for research collaboration, with 48 per cent of all UK articles in 2012 resulting from international collaboration; and, with almost 72 per cent of active researchers internationally mobile in the period 1996-2012 the UK is well placed to continue to drive this research excellence into the future. Indeed, within the Research Councils and Higher Education Institutions novel, multidisciplinary and collaborative approaches have been used to investigate big research challenges facing the UK and the rest of the world for many years and the trend to collaborate and work across disciplinary boundaries is increasing. Public funding for the research base further enhances the delivery of research with excellence. The dual support system, for example, which accounts for almost half of public funds available to researchers, is designed to decentralise the allocation of resources while maintaining the principles of competition in academia[67].

Furthermore, there is a virtuous circle of effective international collaboration and impactful research, with each reinforcing the other. There is a clear positive relationship between the share of internationally co-authored articles and the impact of that research. With **the UK's international co-authorship partnerships typically associated with high field-weighted citation impacts** (Figure 10). However, international collaboration by the academic community must also be accompanied by collaboration with industry if we are to benefit from cutting-edge research. This high-quality research is having an impact on business behaviours, with over 40 per cent of innovating enterprises reporting having co-operation arrangements on some innovation activities[27]. Further, UK corporate users are

[vii] Field Weighted Citation Index is an index that controls for the tendency of certain subject areas or forms of publication to be more likely to attract citations than others. A field-weighted citation impact of 1.0 equals world average in that particular research field.

increasingly downloading UK academic-authored articles (53 per cent of downloads by the corporate sector were of academic research between 2008 and 2012) and there is a net flow of researchers from academia into industry.

Figure 10: Correlation between international co-authorship and FWCI, 2008



Source: Elsevier (2013). ‘International Comparative Performance of the UK Research Base – 2013’

Innovation builds resilience and a dynamic economy

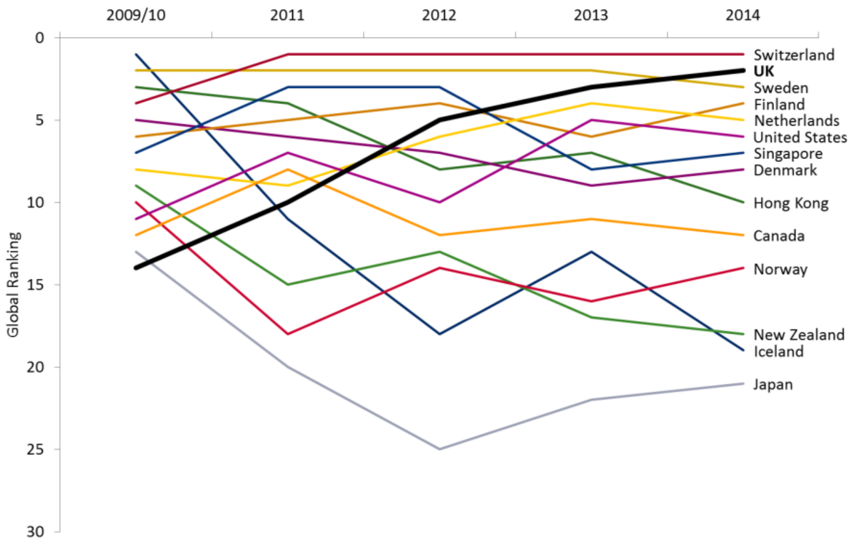
While a world-leading knowledge stock and highly skilled scientific workforce is necessary for expanding the frontier of production possibilities, it is not sufficient for converting that knowledge into real world economic and social gains. In order to realise that potential, the UK must have the mechanisms to share our knowledge assets across the economy; to absorb and apply them in multiple contexts; and to ultimately translate them into commercial success.

The value of innovation for national economic growth is well established; however, our understanding of how and why firms engage in such productivity enhancing activities has also improved. It is unsurprising that firms that persistently invest in R&D have higher productivity (13 per cent higher than those with no R&D spending and 9 per cent more than firms who occasionally invest in R&D), better value added per employee, and more exports[79,80,81]. But what is less well recognised is that while investment in innovation bears inherent risk, **firms with higher innovation intensity grow twice as fast as non-innovative firms[82]; fare better during periods of economic turmoil[83]; and are more likely to still be active after 8 years[84]**. A comprehensive review of the returns literature confirms that R&D investment generates large and persistent returns[16] and although both new-to-market (novel) innovation and new-to-firm (imitation) innovation are important for business performance and growth, novel innovation has been shown to deliver better returns, particularly when facing adverse market conditions[84].

While no perfect measure of innovation performance exists, **the UK does perform among the best in the world on a number of global rankings**. The Global Competitiveness Index[77] places the UK 9th among 37 innovation-driven economies, having risen from 13th in

2009/10[viii]. In terms of the quality of innovation inputs, outputs and infrastructures, **the Global Innovation Index shows the UK now ranking 2nd in 2014, up from 14th in 2009/10**[85] (Figure 11). In the last four years the UK has improved on 5 out of the 6 high-level performance indicators, with the largest increases in infrastructure, human capital and creative outputs; key components of any innovative environment.

Figure 11: UK performance on Global Innovation Index, 2009/10-2014



Source: Cornell, Insead, WIPO (2014). ‘Global Innovation Index 2014’

[viii] The Global Competitiveness Index contains an Innovation ‘pillar’ which measures capacity for innovation; the quality of scientific institutions; business spending on R&D; university-business collaboration; government procurement of advanced technology products; availability of scientists and engineers; and utility patents. On the Innovation pillar, the UK ranked 15th in 2009/10, rising to 12th in the 2014/15 table.

Integrating the knowledge system and the role of government

Innovation is a joint process involving both private and public institutions and rests on a wider innovation environment. Public investment in the system is an investment in the nation's future, ensuring that the UK has a productive economy, healthy society and contributes to a sustainable world. Government support helps the system overcome barriers and unlocks real world economic impact.

Science and innovation are part of a unified knowledge system

Britain's public, private and voluntary sector research and technology organisations together employed 57,200 people in 2012/13 and supported £7.6 billion in gross value added contributions to GDP[86]. A better understanding of how the science and innovation system contributes to economic success, and increased recognition of the complexity and connectivity in the commercialisation process has led to a more holistic and multidimensional approach to policy-making[87]. We now understand the continuous feedbacks between the numerous interdependent agents better: there are a large number of agents with multi-faceted motivations, all interacting within a local, national and international context[11].

In order for the innovation process to function, **it is crucial for the institutions which create knowledge and the organisations which draw upon these developments to work together seamlessly**. Smart, co-ordinated, dynamic and fluid partnerships, often funded by but operated independently of, Government are replacing the narrow relationships of previous generations. Through organisations such as the Research Councils, Innovate UK and others, the knowledge landscape is jointly developing business models which anchor into the science and innovation ecosystem. The Biomedical Catalyst model, for example, has invested over £200m in grants to date, supporting innovation in around 250 small and medium companies and universities, and this has leveraged £100 million of additional private finance. Indeed, analysis of recent trends in system interactions has shown a change in the UK from bilateral collaboration towards a closely connected ecosystem where all stakeholders are integrated in the development process, coordinating resource allocation decisions and engaging through multiple channels. As these interactions become increasingly complex, the importance of the knowledge infrastructure and the ability for skilled people to transition between the science and research institutions and the businesses which harness these ideas becomes more significant.

Firms, the primary agents for commercialising knowledge, face a constant need to solve problems, and they do this by frequently reaching outside the boundaries of the firm and into the knowledge and skills bases. Over 40 per cent of innovating firms report having co-operation arrangements on some innovation activities; 61 per cent report arrangements with private sector partners, while 31 per cent co-operate with the public sector[88]. These interactions and the subsequent applications of knowledge are not a single event; they are a continuous process where past achievements and experiences drive forward our capacity to modify and develop ideas. **Successful firms do not innovate once; instead, they produce a flow of innovations over time**.

Businesses are dependent on the spatial context in which they exist, and there is a growing awareness of the role places have in contributing to the knowledge base and aggregate growth. Recent work defining **the 'knowledge context' of firms looks beyond the industrial space occupied by the innovator and integrates it with the network opportunities and the geography in which firms are located**[89]. There is evidence, for example, that R&D facilities in the pharmaceutical sector are largely determined by proximity of high-quality university chemistry departments, and the location of R&D in the vehicles and machinery industry are associated with possibilities for co-location with production[90]. The UK's 31 largest clusters contribute a fifth of UK gross value added[91] and recent literature has found that clusters have positive impacts on innovation[92].

Businesses have been found to innovate more when their surrounding area is innovative, partly due to knowledge spillovers and agglomeration effects; high growth firms innovate more when they are closely located to other high growth firms that are engaging in R&D[93] and when their surrounding city-region is more innovative[94]. However, co-location is not sufficient to drive innovation; businesses need to interconnect within knowledge contexts that provide the networks and agglomeration effects which support innovation and growth[95]. Evidence shows that although strong innovation performance is not caused by clusters per se, local innovation systems cultivate successful high technology clusters[96].

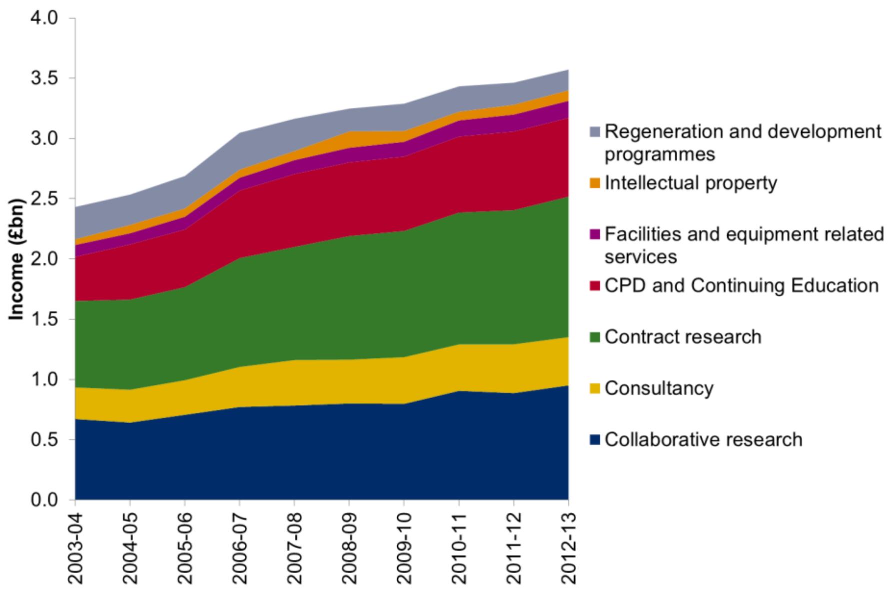
Innovation can contribute to regional rebalancing through productivity growth and employment creation of skilled jobs with wages higher than the regional average. For example, in the Golden Triangle (Oxford-Cambridge-London) employment grew at 2 per cent per annum throughout the downturn where the mean salary of workers was 40 per cent higher than the regional average[97]. It is key that local authorities and Local Enterprise Partnerships (LEPs) have the knowledge and economic intelligence of local comparative advantage in order to effectively target resources where local and national innovation strategies are aligned.

As was highlighted in the Witty Review of Universities and Growth[98], effective engagement with business is central to such networks. Recent analysis has found that the UK performs on a par with the United States in having created and supported the world's most successful technology innovation ecosystem[99]; strong research capability and a culture of entrepreneurialism and innovation were seen as among the criteria most important in that success. Knowledge exchange between the research base and the business sector comes in many forms and academics from all disciplines participate[100]. Research Councils engage with 2,500 businesses, including large corporates and more than 1,000 SMEs[101]. The most recent data on interactions show **a continuing increase of over 45 per cent since 2003/4 in the exchange of knowledge between UK Higher Education Institutions and the public, private and third sectors**. In 2012/13 universities contributed £3.6bn through the commercialisation of new knowledge, and the delivery of knowledge to industrial and public sector partners. UK HEIs earned £1.2 billion from contract research in 2012/13, and a further £1.5 billion of income from consultancy contracts, facilities and equipment, CPD courses, intellectual property, and regeneration and development programmes[102]. Through the Higher Education Innovation Funding

(HEIF) programme, the Government continues to support the evolving interface between academia, industry and the public sector, with some estimates showing that £1 of HEIF investment leading to £6.30 in gross additional knowledge exchange income[103]. Furthermore there is evidence that 80 per cent of HEIs are making changes to improve the effectiveness of knowledge exchange, and three quarters see greater collaboration as key to improved effectiveness[104]. As a result of such activity, the Global Competitiveness Index has consistently ranked the UK in the top 5 globally for university-business collaboration since 2010/11, placing it 4th in 2014/15 (up from 12th in 2007/8)[77].

Such improvements have also been promoted through programmes such as the Knowledge Transfer Network, which helps businesses access the knowledge and expertise they need to thrive; and Knowledge Transfer Partnerships, which facilitate the exchange of capabilities between academia and industry. Indeed, a review of Knowledge Transfer Partnerships concluded that on average, return on investment was around £4.70 to £5.20 of net additional GVA per £1 of public money[105]. Furthermore, such **collaboration has been shown to impact on the absorptive capacity of firms, with the likelihood of employing STEM skills increasing by 28 per cent and the use of technical information rising 57 per cent; and to increase the likelihood that a firm introduces a new-to-market product by 72 per cent[106] (and 77 per cent for SMEs, which account for 60 per cent of Innovate UK support[107])**.

Figure 12: HEBCI income streams, 2003/4-2012/13



Source: HEBCI (2014). ‘Higher Education - Business and Community Interaction Survey 2012-13’

Market and system failures are persistent

Government as a market shaper

Traditional arguments for public investment typically hinge on market failures. However, as recently recognised in a recent Government Economic Service report on innovation, **the public sector is also an important customer of the knowledge base and has a crucial role in shaping and creating markets**. The report noted that government behaviour, through procurement, policy design and regulatory decisions, has an impact on innovation outcomes[22].

Economists have also noted that the Government is uniquely positioned to take a leading role, taking the risks where the private sector is unable, and then ensuring that the rewards from success are returned to society. Government, it is argued, has the necessary long-term perspective across research and innovation; is able to adopt a portfolio approach to system management; and can create the institutional and physical infrastructure which creates confidence and certainty necessary for private sector partners to undertake risky investment with significant social benefits[21].

Evidence of market and system failures

Arguably, in an increasingly open innovation ecosystem, where Government has a leading partnership role[108], together with businesses, academia and our international collaborators, there is an increasingly clear and evident need to address and overcome both market and system failures (see Table 2) and to unlock the value from advancing the frontiers of knowledge.

A study of the prevalence of market and system failures[109] in 24 substantive economic contexts, including energy; the built environment; food; transport; health and care; creative and financial industries; ICT and robotics; and the biosciences, found that while most types of failure could be identified in most contexts. The mix of failures in each context was unique and the emergence of large and complex technical challenges means that coordination failure is becoming increasingly prevalent. The **market and system failure arguments remain across the spectrum and highlight the need for a whole-of-government industrial strategy which recognises the different conditions in different sectors**. The analysis also recognised a range of barriers which result in a long tail of relatively unproductive firms in the UK, including credit constraints and skills. To combat these barriers, in-depth engagement with individual sectors, sub-sectors and types of technology is necessary[3].

As a result of these market failures, the Government operates a number of different interventions, with many targeted on mid-Technology Readiness Levels (the ‘Valley of Death’[110]). There is strong evidence that such **public investment in the knowledge-base can and does leverage the desired extra participation from the private sector**[37]. While some evidence points to an increase in private R&D of approximately £0.70 for every £1 direct invested by government[111], evidence from public medical research points to increases of between £2.2 and £5.1 in private pharmaceutical industry R&D[112,113].

Table 2: Table of market and system failures

		Character of science and technology	Market Power	Externalities	Information asymmetry	Capabilities	Network	Institutional	Infrastructural
Energy	Nuclear energy		****	***	*	**	***	****	****
	Renewable energy		**	****	**		***	****	****
	Oil and Gas	***		**	**	*	**	***	**
	Energy Storage	**	****	****	***		****	***	****
Built environment	Low impact buildings		***	****	**	**	**	**	**
	Future cities			**		**	**		**
Food	Agri-science		**	**	**	**	****	***	**
	Farm-to-fork value chains		****	***	*		****	*	***
Transport	Low carbon vehicles	**	**	**		**	**	**	****
	Intelligent transport systems		**		**		***	**	****
	Civil aviation	**	**			***	**	**	****
Healthcare	Regenerative medicine	**	**		****	**			**
	Assisted Living				**		***	**	****
	Stratified medicine		**	****	**		**	**	
Creative Industries			**	***		***	**	**	
Financial services			**		**	**	****	****	
Satellites and space			**	***	**		****		**
Nanotechnology and Advanced Materials		***	***	*	*	****		****	
ICT	Big data		*	*	*	****	*	*	*
	Cyber security		**	***	****			**	
	Robotics and autonomous systems	**		**	**	**	***	**	**
Electronic, photonics and electrical systems		***	***	**		**	**	**	
Biosciences	Industrial biotechnology			***	***	***	***	***	****
	Synthetic biology	**			****	*	*	**	

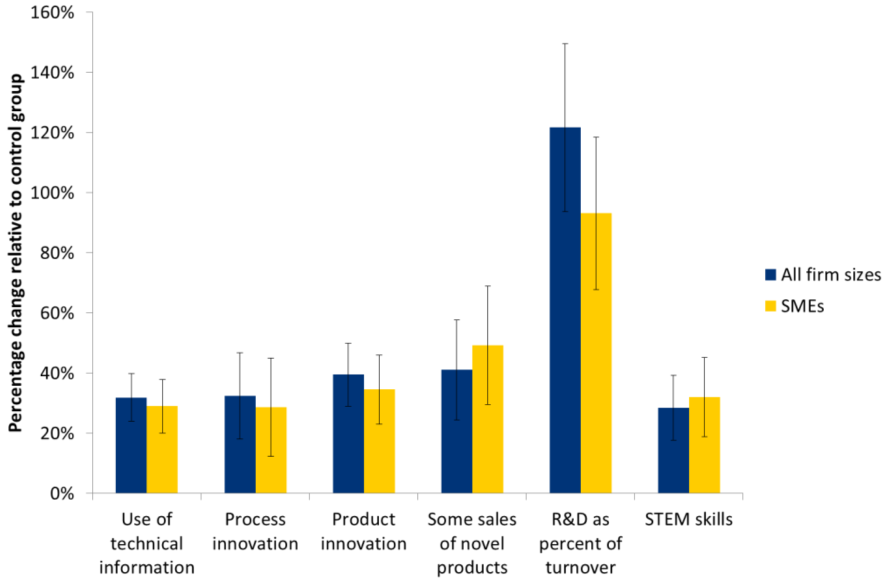
Notes: *** Showstopper, ***Slowing-down (a lot), **Slowing down, *Slowing-down (a little), “blank” No evidence found. Source: BIS (2014). ‘The case for public support of innovation: at the sector, technology and challenge area levels’.

Government action to address market and system failures

It is reported that the cost of innovation; the cost and availability of finance; and excessive risk are the most significant barriers to innovation, with SMEs experiencing this most acutely[114]. Indeed, **access to finance has been found to be the most problematic factor in doing business in the UK**[77] and, an increasing short-termism in private sector finance for research and innovation is increasingly incompatible with the long time-lags which characterise investments in innovation[115]. To address these barriers and unlock the innovative potential, the Government deploys a mixture of both direct and indirect support in broadly equal amount. The UK has one of the most competitive tax environments[116], with the total amount of R&D support claimed in 2012/13 amounting to £1.4 billion (up

£150 million on 2011/12)[117], and rising. This provided relief to over 15,500 businesses and supported around £13.2bn of investment in 2012-13. UK businesses also reported that 9 per cent, or £1.6bn[33], of Business R&D expenditure was funded by government in 2013.

Figure 13: Impact of direct government support: percentage change in likelihood



Source: BIS (2014). 'Estimating the Effect of UK Direct Public Support for Innovation'.

Both direct and indirect forms of R&D support have been shown to leverage additional private funding[111,118], and at a system level, there is evidence of complementarity from employing both measures simultaneously[119]; albeit grant-based forms of innovation have been shown to support the broader development of firms' absorptive capacity in a way that indirect measures do not[120]. The evidence shows that they have a positive long run influence on firms' behaviour and absorptive capacity through creation and more effective use of networks[121]. **In addition to improving firm survival by nearly 3 per cent[84], new analysis finds that UK grant support substantially increases UK firms' innovation performance**[106] (Figure 13). The analysis found that large firms and SMEs as a group were more likely to: invest more in R&D; collaborate; employ STEM graduates; use technical information; engage in product innovation; engage in process innovation; and introduce novel products to market[ix]. Furthermore, the effects were even larger where businesses collaborate with other partners. These findings accord with previous economic evaluations of UK innovation grant support programmes for SMART and Collaborative R&D which estimated benefit-cost ratios in the order of £9:1 and £7:1 respectively[122,123].

However, impediments to a successful knowledge system do not end at finance. The Catapult Network, operated through Innovate UK (the UK's lead innovation agency), helps to overcome a number of other barriers by providing facilities targeted at mid-range Technology Readiness Levels, which would suffer from natural monopoly, or indivisibility issues, due to their high cost. The recent Hauser Review[124] outlined how, despite their

[ix] Receiving a grant increases a business's own spending on R&D by approximately 30 per cent and makes them over 40 per cent more likely to introduce novel products to market; 40 per cent more likely to engage in product innovation and almost 30 per cent more likely to employ STEM graduates.

nascent state, Catapults are demonstrating positive early impacts, and are building on the existing competencies of the intermediate sector. They help anchor investment in the UK from global organisations who invest their R&D resources in the localities where the environment is most suitable and in particular where there is a strong level of Government support and investment[125, 126].

As a programme targeted at large global markets, through development of multi-application and disruptive technologies, based on an understanding of open innovation, Catapults have large positive spillover effects[127]. However, even when spillover effects were not accounted for, an evaluation conducted on the economic impact of Collaborative R&D, which constitute a third of Catapults funding, found that for every £1 of public investment was associated with a GVA return of £6.71, once allowances are made for deadweight and displacement[123]. Furthermore, the Collaborative R&D programme helps commercialisation by increasing the speed, scale and scope of activities which would have gone ahead. 70 per cent of projects definitely would not go ahead without government support and, of those that would have proceeded without support, 83 per cent would be delayed by one to two years and more than one in five would be delayed by 3-5 years. More than half of projects supported would have done occurred at a smaller scale and 35 per cent with a different scope. In a globally competitive environment, commercialising swiftly and effective can make all the difference between being a market leader or a market follower. In addition to funding research to progress fundamental understanding in given field, where business investment is traditionally very low (typically only 5 per cent of business R&D expenditure in the UK)[x], part of this role includes provision of protection for intellectual property (IP) rights (where the UK ranks first in the world for competitiveness)[128]. A careful balance must be struck whereby innovators are able to appropriate the returns of their risk, but also remain sufficiently competitive to prevent complacency and maximise returns to society.

Conclusion

The need to expand the frontiers of knowledge and capability is amplified by the vast social and environmental challenges facing nations globally. The knowledge base is a vast and complex ecosystem, and there are a number of characteristics which mean that government leadership is necessary to remain at the forefront of solving these challenges.

Science and research are the ambition to expand our understanding and to find solutions to practical problems facing our world and our society, while innovation is the application of that knowledge to the production of goods and services; either through new and better

[x] Overall, it appears that the business sector engages in only a small proportion of basic research. Recent case study evidence from the aerospace and pharmaceutical sectors (Frontier Economics, 2014) considers the interaction between the business sector and the research base finding that some companies rely on partnerships with academic and public sector institutions for the pure research which may generate future applied research.

quality goods or enhanced productions processes. The unifying theme throughout the analysis has been the importance of enhancing and supporting the connections between the various components of the knowledge ecosystem; and the critical need to get the right skills, in the right place, at the right time if we are to successfully to translate our world-leading research into internationally-competitive and innovative solutions.

It is clear that the returns to investment in science and innovation are significant, but they will require patience, and the courage to take risks where the private sector would not without partnership with Government. The challenge facing policy-makers of the future will be in developing the necessary whole-of-government approach which recognises the vital role that each organisation plays in the ecosystem; provides a stable foundation; but is agile enough to adapt across sectors, and to respond to the emerging opportunities presented by existing at the very frontiers of knowledge.

Future evidential demands

The best policymaking requires the best analysis and evidence. As the system of knowledge evolves and the roles of business, government and academia change, so too must our understanding of the system. As a nation we must continue to expand the frontiers of our knowledge to ensure that society is well-formed. Policy-makers especially, must therefore seek to develop the evidence on:

- the role of the research, innovation and skills in achieving our social and economic objectives;

- the determinants of, and obstacles to, maintaining a world class research base; and building and nurturing innovation and absorptive capacity;

- effective policy-design, by evaluating the effectiveness of different policy approaches and understanding how science and innovation policy interacts with broader governmental policy including skills and spatial policy;

- performance of the knowledge base, by benchmarking against the best in the world;

- conditions for innovation by deepening and enhancing our understanding of non-R&D knowledge-based investment; and,

- the role of local eco-systems in shaping innovation at the firm level and contributing to economic growth.

Endnotes

[1] Schumpeter (1942). Capitalism, Socialism and Democracy, London: Routledge.

[2] Department for Business, Innovation and Skills (2011). 'Innovation and Research strategy for Growth: Economics Paper 15. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/32445/11-1386-economics-innovation-and-research-strategy-for-growth.pdf

[3] Exeter Business School, Brighton Business School and SPRU – Science and Technology Policy Research (2014). 'UK Innovation Survey: Innovative Firms and Growth'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289234/bis-14-643-uk-innovation-survey-highly-innovative-firms-and-growth.pdf

[4] National Centre for Universities and Business (2014). 'The state of the Relationship Report 2014'. Available at: http://www.ncub.co.uk/index.php?option=com_docman&task=doc_download&gid=97&Itemid=

[5] Office for National Statistics (2014). 'Measuring and capitalising research & development in the UK National Accounts'. Available at: http://www.ons.gov.uk/ons/guide-method/method-quality/specific/economy/national-accounts/articles/2011-present/measuring-and-capitalising-research---development-in-the-uk-national-accounts.pdf

[6] Griliches (1991). 'The search for R&D spillovers'. NBER Working Paper 3768. Available at: http://www.nber.org/papers/w3768.pdf

[7] Arthur (1994). 'Increasing Returns and Path Dependence in the Economy'. The University of Michigan Press.

[8] Goodridge, Haskel and Wallis (2014). 'UK investment in intangible assets'. Available at: http://www.nesta.org.uk/sites/default/files/1402_working_paper_-_uk_investment_in_intangible_assets_report_for_nesta.pdf

[9] Organisation for Economic Cooperation and Development (2005). 'The Measurement of Scientific and Technological Activities: Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual, Third Edition'. Prepared by the Working Party of National Experts on Scientific and Technology Indicators. OECD, Paris, para. 71.

[10] Organisation for Economic Cooperation and Development (2013). 'Supporting Investment in Knowledge Capital, Growth and Innovation'. OECD Publishing. Available at: http://dx.doi.org/10.1787/9789264193307-en

[11] Department for Business, Innovation and Skills (2014). 'Insights from International benchmarking of the UK science and innovation system'. BIS Analysis Paper 3. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277090/bis-14-544-insights-from-international-benchmarking-of-the-UK-science-and-innovation-system-bis-analysis-paper-03.pdf

[12] Love and Roper (2013). 'SME Innovation, Exporting and Growth: A review of existing evidence'. Enterprise Research Centre. White Paper Number 5. Available at: http://enterpriseresearch.ac.uk/wp-content/uploads/2013/12/ERC-White-Paper-No_5-Innovation-final.pdf

[13] Enterprise Research Centre (2014). 'Growing Global – Moving up the exporting ladder'. Insight Paper. June 2014. Available at: http://enterpriseresearch.ac.uk/wp-content/uploads/2014/06/ERC-Insight-Conf-2014-Innov.pdf

[14] Aghion and Howitt (2007). Capital, Innovation and Growth Accounting. Available at: http://www.econ.brown.edu/fac/Peter_Howitt/publication/Solow%20volume.pdf

[15] Department for Business, Innovation and Skills (2012). Annual Innovation Report. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/34805/12-p188-annual-innovation-report-2012.pdf

[16] Frontier Economics (2014). 'Rates of return to investment in science and innovation'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/333006/bis-14-990-rates-of-return-to-investment-in-science-and-innovation-revised-final-report.pdf

[17] Griffith, R., Redding, S. & Van Reenan, J. (2003). R&D and Absorptive Capacity: Theory and Empirical Evidence. Scandinavian Journal of Economics, 105, 99-118.

[18] Department for Business, Innovation and Skills (2014). 'Public Attitudes to Science'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/348830/bis-14-p111-public-attitudes-to-science-2014-main.pdf

[19] Nesta (2014). 'Speaking to the Innovation Population'. Available at: http://www.nesta.org.uk/sites/default/files/speaking_to_the_innovation_population.pdf

[20] Government Office for Science (2014): 'Innovation: Managing risk, not avoiding it'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/376505/14-1190b-innovation-managing-risk-evidence.pdf

[21] Mazzucato (2013). 'The Entrepreneurial State: Debunking Public vs. Private Sector Myths'.

[22] Government Economic Service (2014). 'Innovation and economic growth: Government Economic Service report'. Available at: https://www.gov.uk/government/publications/innovation-and-economic-growth-government-economic-service-report

[23] Rouvinen (2002). 'R&D – Productivity dynamics: Causality, lags and dry holes'. Available at: http://www.ucema.edu.ar/publicaciones/download/volume5/rouvinen.pdf

[24] Mansfield (1991, 1998). 'Academic research and industrial innovation: An update of empirical findings'. Available at: http://sjbae.pbworks.com/f/Mansfield_1998.pdf

[25] Wellcome (2008). Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK. Available at: http://www.wellcome.ac.uk/stellent/groups/corporatesite/@sitestudioobjects/documents/web_document/wtx052110.pdf

[26] Organisation for Economic Cooperation and Development (2014). 'Global Value Chains: Challenges, opportunities and implications for policy'. Available at: http://www.oecd.org/tad/gvc_report_g20_july_2014.pdf

[27] Department for Business, Innovation and Skills (2014). 'First findings from the UK innovation survey 2013: knowledge and innovation analysis'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/301385/14-p107a-first-findings-from-the-ukis-2013.pdf

[28] Organisation for Economic Cooperation and Development (2014). Main Science and Technology Indicators. Available at: http://stats.oecd.org

[29] Office for National Statistics (2014). 'Gross Domestic Expenditure on Research and Development, 2012'. Available at: http://www.ons.gov.uk/ons/rel/rdit1/gross-domestic-expenditure-on-research-and-development/2012/index.html

[30] Coccia (2009). 'What is the optimal rate of R&D investment to maximize productivity growth?'. Available at: http://www.sciencedirect.com/science/article/pii/S0040162508000383

[31] Organisation for Economic Cooperation and Development (2013). 'OECD Science, Technology and Industry Scoreboard 2013: Innovation for Growth'. OECD Publishing. Available at: http://dx.doi.org/10.1787/sti_scoreboard-2013-en

[32] Address by the Minister of Science and Technology, Naledi Pandor MP, to the 19th World Congress of the International Federation of Automatic Control (IFAC), ICC, Cape Town, Sunday 24 August 2014. http://www.dst.gov.za/index.php/media-room/media-room-speeches/minister/1051-address-by-the-minister-of-science-and-technology-naledi-pandor-mp-to-the-19th-world-congress-of-the-international-federation-of-automatic-control-ifac-icc-cape-town-sunday-24-august-2014

[33] Office for National Statistics (2014). 'Business Enterprise Research and Development, 2013'. Available at: http://www.ons.gov.uk/ons/rel/rdit1/bus-ent-res-and-dev/2013/index.html

[34] Annual Business Survey (2014). ABS Data 2009-2012

[35] European Commission (2014). 'Innovation Union Scoreboard 2014'. Available at: http://ec.europa.eu/enterprise/policies/innovation/files/ius/ius-2014_en.pdf

[36] EY (2014). 'EY's attractiveness survey, UK 2014: Winning the race, but still more opportunity'. Available at: http://www.ey.com/Publication/vwLUAssets/EY_UK-Attractiveness-Index-2014-web/$FILE/1483927_UK%20Attractiveness%20Survey%202014_FINAL_Web.pdf

[37] Hughes, Haskel and Bascavusoglu-Moreau (2014). 'The Economic Significance of the UK Science Base'. Available at: http://sciencecampaign.org.uk/UKScienceBase.pdf

[38] European Commission (2014). FP7 grant agreements and participants database. Version 17.0. Released 15 October 2014.

[39] Riley, R. and C. Robinson (2011). 'UK Economic Performance: How Far do Intangibles Count?'. Innodrive working paper No. 14.

[40] Adams, Cohen and Levinthal (1990). 'Absorptive Capacity: A New Perspective on Learning and Innovation'. Administrative Science Quarterly. Available at: http://www.jstor.org/stable/2393553

[41] Times Higher Education (2014). Times Higher Education World Rankings 2014-15. Available at: http://www.timeshighereducation.co.uk/world-university-rankings/2014-15/world-ranking/range/001-200/order/country%7Casc

[42] Times Higher Education (2014). 'The 100 most international universities in the world'. Available at: https://secure.timeshighereducation.co.uk/news/the-100-most-international-universities-in-the-world/1/2010783.article

[43] HEFCE (2013). '2013 Teaching Quality Information data'. Available at: http://www.hefce.ac.uk/whatwedo/lt/publicinfo/nss/data/2014/

[44] Organisation for Economic Cooperation and Development (2014). 'Doctoral graduation rate in science and engineering'. Data extracted on 21 Oct 2014 from OECD.Stat.

[45] Organisation for Economic Cooperation and Development (2013). 'OECD Science, Technology and Industry Scoreboard 2013: Innovation for Growth'. OECD statistics population and education data.

[46] Organisation for Economic Cooperation and Development (2013). 'OECD Skills Outlook 2013: First Results from the Survey of Adult Skills'. OECD Publishing. Paris. Available at: http://dx.doi.org/10.1787/9789264204256-en

[47] Hausmann, Hidalgo et al. (2011). 'The Atlas of Economic Complexity'. Puritan Press. Cambridge MA. Available at: http://www.chidalgo.com/Atlas/

[48] Schmidt (2005). 'Absorptive Capacity – One Size Fits All? A Firm-Level Analysis of Absorptive Capacity for Different Kinds of Knowledge'. ZEW – Centre for European Economic Research Discussion Paper No 05-072. Available at: http://ftp.zew.de/pub/zew-docs/dp/dp0572.pdf

[49] Vahter, Love and Roper (2013). 'Openness and innovation performance: are small firms different?'. Enterprise Research Centre Research Paper No.12. Available at: http://enterpriseresearch.ac.uk/wp-content/uploads/2014/01/ERC-RP12-ERC-Vahter-et-al-Open-Innovation.pdf

[50] Organisation for Economic Cooperation and Development (2012). 'PISA 2012 Results in Focus: What 15-year-olds know and what they can do with what they know' . Available at: http://www.oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf

[51] Department for Education (2014). 'Provisional GCSE and equivalent results in England: 2013 to 2014'. Available at: https://www.gov.uk/government/statistics/provisional-gcse-and-equivalent-results-in-england-2013-to-2014

[52] Department for Education (2014). 'A level and other level 3 results: 2013 to 2014 (provisional)'. Available at: https://www.gov.uk/government/statistics/a-level-and-other-level-3-results-2013-to-2014-provisional

[53] UCAS data. Available at: http://www.ucas.com/data-analysis

[54] Higher Education Statistics Authority. Available at: https://www.hesa.ac.uk

[55] Department for Business, Innovation and Skills (2011). 'Estimating the Value to the UK of Education Exports'. Research Paper Number 46. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/32395/11-980-estimating-value-of-education-exports.pdf

[56] Organisation for Economic Cooperation and Development (2014). Education at a Glance 2014. Available at: http://www.oecd.org/edu/Education-at-a-Glance-2014.pdf. Table C4.4

[57] Universities UK (2014). 'International students in Higher Education: the UK and its competition'. Available at: http://www.universitiesuk.ac.uk/highereducation/Documents/2014/InternationalStudentsInHigherEducation.pdf

[58] Women in Science, Technology and Engineering (2010). 'Women and men in science, engineering and technology: the UK statistics guide 2010'. Available at: http://www.theukrc.org/files/useruploads/files/final_sept_15th_15.42_ukrc_statistics_guide_2010.pdf

[59] Office for National Statistics (2014). 'Education and training statistics for the UK: 2014'. Available at: https://www.gov.uk/government/statistics/education-and-training-statistics-for-the-uk-2014

[60] Institute of Physics (2012). 'It's different for girls'. Available at: http://www.iop.org/education/teacher/support/girls_physics/file_58196.pdf

[61] Individualised Learner Record (2014). 'Demographic Summary of FE and Skills Participation (2012/13)'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/354717/feandskills-allages-demographics-participation-1213.xls

[62] Higher Education Statistics Authority (2014). 'Qualifications obtained by students on HE courses at HEIs in the UK by sex, subject area and level of qualification obtained 2008/09 to 2012/13'. Available at: https://www.hesa.ac.uk/dox/pressOffice/sfr197/280607_student_sfr197_1213_all_tables.xlsx

[63] Forthcoming RCUK Doctoral Impact Report

[64] London Economics (2011). 'The returns to Higher Education Qualifications'. BIS Research Paper Number 45. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/32419/11-973-returns-to-higher-education-qualifications.pdf

[65] Lindley and Machin (2013). 'The Postgraduate Premium: Revisiting Trends in Social Mobility and Educational Inequalities in Britain and America'. Available at: http://www.suttontrust.com/wp-content/uploads/2013/02/Postgraduate-Premium-Report.pdf

[66] HEFCE (2013). 'Postgraduate education in England and Northern Ireland'. Overview Report 2013. Available at: http://www.hefce.ac.uk/media/hefce/content/pubs/2013/201314/Postgraduate%20education%20in%20England%20and%20Northern%20Ireland%20Overview%20report%202013.pdf

[67] Hughes and Kitson (2013). 'The Dual Funding Structure for Research in the UK: Research Council and Funding Council Allocation Methods and the Pathways to Impact of UK Academics'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/181652/bis-13-545-dual-funding-structure-for-research-in-the-uk-research-council-and-funding-council-allocation-methods-and-the_pathways-to-impact-of-uk-academics.pdf

[68] Hughes and Martin (2012). 'Enhancing Impact: The Value of Public Sector R&D'. Available at: http://www.cbr.cam.ac.uk/pdf/Impact%20Report%20-%20webversion.pdf

[69] UK Commission for Employment and Skills (2014). 'Working Futures 2012-2022'. Evidence Report 83. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298510/working-futures-2012-2022-main-report.pdf

[70] Department for Business, Innovation and Skills (2014). 'Research Council Impact reports 2013: Trends in inputs, outputs and outcomes'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/301473/bis-14-654-research-council-impact-reports-2013-trends-in-inputs-outputs-and-outcomes_formatedit.pdf

[71] DIUS (2009). The Demand for Science, Technology, Engineering and Mathematics (STEM) Skills. Available at: http://www.bis.gov.uk/assets/biscore/corporate/migratedD/publications/D/Demand_for_STEM_Skills

[72] CRAC (2011). 'STEM Graduates in Non-STEM Jobs'. BIS Research Paper Number 30. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/32379/11-771-stem-graduates-in-non-stem-jobs.pdf

[73] Social Market Foundation (2013). In the Balance: The STEM Human Capital Crunch. Available at: http://www.smf.co.uk/files/8713/6344/7820/In_the_Balance.pdf

[74] Royal Academy of Engineering (2012). 'Jobs and Growth: the importance of engineering skills to the UK economy'. Available at: http://www.raeng.org.uk/publications/reports/jobs-and-growth

[75] UK Commission for Employment and Skills (2013). 'The Supply of and Demand for High-Level STEM Skills'. Evidence Report 77. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/302973/evidence-report-77-high-level-stem-skills_1_.pdf

[76] Institute for Public Policy Research (2014). 'Winning the Global Race'. Available at: http://www.ippr.org/assets/media/publications/pdf/winning-global-race_June2014.pdf

[77] World Economic Forum (2014). Global Competitiveness Report 2014-15. Available at: http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2014-15.pdf

[78] Elsevier (2013). 'International Comparative Performance of the UK Research Base – 2013'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263729/bis-13-1297-international-comparative-performance-of-the-UK-research-base-2013.pdf

[79] Cefis, E., Ciccarelli, M. (2005), ‘Profit differentials and innovation’, Economics of innovation and new technologies 14, Routledge.

[80] Cefis, E., Orsenigo, L. (2001), ‘The persistence of innovative activities: A cross-countries and cross-sectors comparative analysis’, Research Policy

[81] Lööf et al (2012), ‘R&D Strategy and Firm Performance: What is the Long-Run Impact of Persistent R&D?’ in Innovation & Growth. From R&D Strategies of Innovating Firms to Economy-Wide Technological Change. Oxford University Press.

[82] Nesta (2009). ‘The vital 6 per cent how high-growth innovative businesses generate prosperity and jobs’. Available at: http://www.nesta.org.uk/sites/default/files/vital-six-per-cent.pdf

[83] Birkbeck (2014). Innovation, skills and performance in the downturn. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287901/bis-14-652-innovation-skills-and-performance-in-the-downturn.pdf

[84] Enterprise Research Centre (2014). ‘Innovation, Innovation Strategy and Survival’. Research Paper No 17. Available at: http://enterpriseresearch.ac.uk/publications/innovation-innovation-strategy-survival/

[85] Cornell, Insead, WIPO (2014). ‘Global Innovation Index 2014’. Available at: http://www.globalinnovationindex.org/userfiles/file/reportpdf/GII-2014-v5.pdf

[86] Oxford Economics (2014). 'The impact of the innovation, research and technology sector on the UK economy'. Available at: http://www.airto.co.uk/docs/AIRTO%20-%20Oxford%20Economics%202014.pdf

[87] Nesta (2013). ‘Systems Innovation’. Discussion Paper. Available at: http://www.nesta.org.uk/sites/default/files/systems_innovation_discussion_paper.pdf

[88] Department for Business, Innovation and Skills (2014). ‘First findings from the UK Innovation Survey 2013 [revised]’. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/364760/bis-14-p107-first-findings-from-the-uk-innovation-survey-2013-knowledge-and-innovation-analysis.pdf

[89] Roper, Love and Zhou (2014). ‘Knowledge context, learning and innovation: an integrating framework’. ERC Research Paper No.20. Available at: http://enterpriseresearch.ac.uk/wp-content/uploads/2014/06/ERC-RP20-Knowledge-Context-Roper-et-al.pdf

[90] Abramovsky and Simpson (2008). ‘Geographic proximity and firm-university innovation linkages: evidence from Great Britain’.Available at: http://eprints.ucl.ac.uk/14737/1/14737.pdf

[91] Centre for Cities (2014). ‘Industrial Revolutions: capturing the growth potential’. Available at: http://www.centreforcities.org/assets/files/2014/14-06-26-Final-web-Industrial-Revolutions.pdf

[92] Uyarra and Ramlogan (2012). ‘The Effects of Cluster Policy on Innovation’. Available at: http://www.innovation-policy.org.uk/share/05_The%20Effects%20of%20Cluster%20Policy%20on%20Innovation.pdf

[93] Bondibene, Mason, Robinson (2013). ‘Firm growth and innovation in UK city regions’. Available at: https://www.nesta.org.uk/sites/default/files/firm_growth_and_innovation_in_uk_city_regions.pdf .

[94] Sena, Hart and Bonner (2012). ‘Innovation and UK High-Growth Firms’. Available at: http://www.nesta.org.uk/sites/default/files/innovation_and_uk_high-growth_firms.pdf

[95] Chapain, Cooke, et al (2010). ‘Creative Clusters and Innovation’. Available at: http://www.nesta.org.uk/sites/default/files/creative_clusters_and_innovation.pdf

[96] Martin, R., and Sunley, P. (2010). ‘Regional competitiveness: clusters or dynamic comparative advantage?’

[97] Centre for Cities (2014). ‘Industrial Revolutions: capturing the growth potential’. Available at: http://www.centreforcities.org/assets/files/2014/14-06-26-Final-web-Industrial-Revolutions.pdf

[98] Witty (2013). 'Encouraging a British Invention Revolution: Sir Andrew Witty's Review of Universities and Growth – Final report and recommendations'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249720/bis-13-1241-encouraging-a-british-invention-revolution-andrew-witty-review-R1.pdf

[99] Graham (2014). Creating university-based entrepreneurial ecosystems: evidence from emerging world leaders. Available at: http://www.rhgraham.org/RHG/Recent_publications_files/MIT%3ASkoltech%20entrepreneurial%20ecosystems%20report%202014%20_1.pdf

[100] Abreu et al. (2009). 'Knowledge exchange between academics and the business, public and third sectors'. Available at: http://www.cbr.cam.ac.uk/pdf/AcademicSurveyReport.pdf

[101] Research Council UK (2014). 'Impact Report 2013'. Available at: http://www.rcuk.ac.uk/RCUK-prod/assets/documents/publications/2013Impactreport.pdf

[102] Higher Education Business Community Interaction Survey (2014). 'Higher Education - Business and Community Interaction Survey 2012-13'. Available at: http://www.hefce.ac.uk/whatwedo/kes/measureke/hebci/

[103] Ulrichsen (2014). 'Knowledge Exchange Performance and the Impact of HEIF in the English Higher Education Sector'. Available at: http://www.hefce.ac.uk/media/hefce/content/pubs/indirreports/2014/keperformanceandtheimpactofheif/2014_keheifimpact.pdf

[104] PACEC (2012). 'Strengthening the Contribution of English Higher Education Institutions to the Innovation System: Knowledge Exchange and HEIF Funding'. Available at: https://secure.pacec.co.uk/documents/HEIF11-15-FullReport.pdf .

[105] Regenris Consulting (2010). 'Knowledge Transfer Partnerships Strategic Review'. Available at: http://webarchive.nationalarchives.gov.uk/20140827133341/http://www.innovateuk.org/_assets/pdf/corporate-publications/ktp%20strategic%20review%20feb%202010.pdf

[106] Department for Business, Innovation and Skills (2014). 'Estimating the Effect of UK Direct Public Support for Innovation'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/369650/bis-14-1168-estimating-the-effect-of-uk-direct-public-support-for-innovation-bis-analysis-paper-number-04.pdf

[107] Previously unpublished Innovate UK analysis.

[108] Big Innovation Centre (2011). 'Making the UK a Global Innovation Hub: How business, finance and an enterprising state can transform the UK'. Available at: http://biginnovationcentre.com/Assets/Docs/Reports/Making%20the%20UK%20a%20Global%20Innovation%20Hub.pdf

[109] Technopolis Ltd (2014). 'The Case for Public Support of Innovation: at the sector, technology and challenge area levels'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/334369/BIS_14_852_The_Case_for_Public_Support_of_Innovation.pdf

[110] House of Commons Science and Technology Committee (2013). 'Bridging the Valley of Death: Improving the commercialisation of research'. Eighth report of Session 2012-13. Available at: http://www.publications.parliament.uk/pa/cm201213/cmselect/cmsctech/348/348.pdf

[111] Dominique Guellec & Bruno Van Pottelsberghe De La Potterie (2003). 'The impact of public R&D expenditure on business R&D'. Economics of Innovation and New Technology, 12:3, 225-243. Available at: http://dx.doi.org/10.1080/10438590290004555

[112] Toole (2007). 'Does public scientific research complement private investment in research and development in the pharmaceutical industry?'. Journal of Law and Economics 2007; 50:81-104.

[113] Ward and Dranove (1995). 'The vertical chain of research and development in the pharmaceutical industry'. Economic Inquiry 1995; 33:70-87.

[114] Department for Business, Innovation and Skills (2012). 'UK innovation survey 2011: statistical annex [revised]'. Available at: https://www.gov.uk/government/statistics/uk-innovation-survey-2011-statistical-annex-revised

[115] Mazzucato, M., & Penna, C. (2014). 'Beyond market failures: The market creating and shaping roles of State investment banks'. Available at: http://www.astrid-online.it/Responsabi/Documenti/2014-21_SWPS_Mazzucato-and-Penna.pdf

[116] Organisation for Economic Cooperation and Development (2013). Based on OECD R&D tax incentives questionnaire and publicly available sources. June 2013. Data and notes are available at: http://dx.doi.org/10.1787/888932891150

[117] HM Revenue and Customs (2014). Research and Development Tax Credit Statistics. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/356382/Research_and_Development_Tax_Credits_-_August_2014.pdf

[118] Becker (2014). 'Public R&D policies and private R&D investment: A survey of the empirical evidence'. Journal of Economic Surveys Vol. 00, No. 0, pp. 1-26. Available at: http://authorservices.wiley.com/bauthor/onlineLibraryTPS.asp?DOI=10.1111/joes.12074&ArticleID=1329672

[119] Cunningham et al. (2013). 'Innovation policy mix and instrument interaction: A review'. Available at: http://www.innovation-policy.org.uk/share/19_Policy%20mix_linked.pdf

[120] Roper and Hewitt-Dundas (2014). 'The legacy of public subsidies for innovation: input, output and behavioural additionality effects'. Enterprise Research Centre. Available at: http://druid8.sit.aau.dk/druid/acc_papers/mmccvvc8ou66e4xmq65ee49xpd3i.pdf

[121] Griffith, R., Redding, S. & Van Reenan, J. (2003). 'R&D and Absorptive Capacity: Theory and Empirical Evidence'. London: LSE Research Online. Available at: http://eprints.lse.ac.uk/209/

[122] PACEC (2009). 'Evaluation of Grant for Research and Development and SMART'

[123] PACEC (2011). 'Evaluation of the Collaborative Research and Development Programmes'.

[124] Hauser (2014). 'Review of the Catapult network: recommendations on the future shape, scope and ambition of the programme'. Available at: https://www.gov.uk/government/publications/catapult-centres-hauser-review-recommendations

[125] Oxford Economics (2008). 'Study of the impact of the Intermediate Research and Technology Sector on the UK Economy'. Available at : http://www.airto.co.uk/oxfordeconomics.pdf

[126] Institute for Fiscal Studies (2006). 'University Research and The Location Of Business R&D'. Available at: http://www.ifs.org.uk/wps/wp0702.pdf

[127] ICF GHK (2014). 'An Economic Analysis of Spillovers From Programmes of Technological Innovation Support'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/288110/bis-14-653-economic-analysis-of-spillovers-from-programmes-of-technological-innovation-support.pdf

[128] Taylor Wessing (2014). 'Global IP Index 2013: The fourth report'. Available at: http://www.taylorwessing.com/ipindex/docs/executive_summary_table.pdf

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