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# ENHANCING IMPACT

## THE VALUE OF PUBLIC SECTOR R&D



By Alan Hughes and Ben Martin

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# **ENHANCING IMPACT**

## **THE VALUE OF PUBLIC SECTOR R&D**

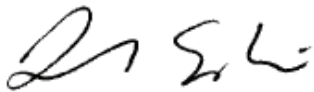
Enhancing Value Task Force

Alan Hughes and Ben R. Martin

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This is the second in a series of linked reports on gaining the most value from UK research, and in particular its publicly-funded research. The first report sets the UK's spend on R&D in an international context, and this follow-up assesses the impact of that expenditure. It highlights the many benefits of publicly-funded research, but stresses the vital importance of moving from simple measures of success, such as university spin-outs and patents, to a more nuanced understanding of the connections between public and private sectors in a system of knowledge production and innovation.



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## Executive Summary

1. This report reviews the evidence relating to the impact of publicly funded research, especially UK university research funded by the Higher Education Funding Councils and the Research Councils through the dual-support system. The allocation of public sector funding for university research in the UK is increasingly conditioned by the need to demonstrate 'impact'.
2. Out of the total UK R&D expenditure of £26.4 billion in 2010, government funded £8.5 billion (32%). £7.1 billion of R&D (27%) was carried out by the Higher Education Sector. The Research Councils spent £2.9 billion and the Funding Councils £2.3 billion, the former having increased by some 50% in real terms over the period 2001-2010, to a large extent reflecting the introduction of full economic costing for university research.
3. The introduction of policies requiring that publicly funded research should reflect the needs of users and should have an 'impact' has led to concern that basic research may be threatened. However, the old dichotomy between 'basic' and 'applied' research is misleading and indeed increasingly irrelevant.
4. It is better to think of different categories of research using Stokes' quadrants – i.e. Bohr's Quadrant ('pure' basic research), Edison's Quadrant (applied research) and Pasteur's Quadrant (user-inspired basic research or 'strategic research'). Much publicly funded research falls into Pasteur's Quadrant.
5. A survey of academics showed that 35% of research funded by Research Councils corresponded to Pasteur's Quadrant, compared with 21% for 'pure' basic research. However, there is no evidence that funding for the latter has suffered over the period since 2000 – indeed its share has increased somewhat.
6. In attempting to assess the impact of publicly funded research, one needs to bear in mind a number of important conceptual issues. In particular, the exploitation of publicly funded research often depends on private sector organisations possessing the requisite absorptive capacity and complementary assets and in them making the necessary investment, factors outside the control of the publicly funded researchers.
7. Hence, the issue is not so much about isolating and assessing the impact of publicly funded research per se nor about determining its optimal level in isolation. It is instead about analysing how best to understand and manage the connections between differently funded and motivated research efforts in an overall *system* of knowledge production and innovation.
8. Previous studies have identified a number of different channels or 'pathways to impact' through which research in the university base may contribute to innovation. These include: increasing the stock of useful knowledge; the supply of graduates; the creation of new instrumentation of methods; the development of new networks; university-based problem-solving and contract research; the enhancement of technological problem-solving capacity; the generation of new firms; and the provision of 'social knowledge'.
9. Some of these channels are more amenable to quantitative assessment of impact, others less so, although these may be at least as important. In addition, the time-scale to the main impact may

be a couple of decades or more, long after the assessment has been carried out. Furthermore, the longer the time-scale, the greater the importance of complementary investments necessary to exploit the potential impact but the harder it becomes to distinguish the effects of the original publicly funded research from all the other factors affecting the final outcome and impact.

10. For some types of research, in particular social and economic research, the impact to be assessed may be in terms of policy development, in which case the ultimate socio-economic impact may be negligible or negative depending upon the success or otherwise of the policy itself.
11. Studies that have attempted to come up with a quantitative measure of economic impact or rate of return invariably involve making a host of simplifying but questionable assumptions about the underlying nature of the links between inputs and outputs, the weights to be attached to each 'factor' affecting the output and impact on output, and the time-lags between the application of a particular input (e.g. publicly funded research) and its associated output.
12. An emphasis on process and complementary investments highlights the importance of understanding the multiple pathways through which knowledge can diffuse across organisational boundaries into commercial and economic applications, and invites a 'narrative' approach to impact assessment, complementing the quantification of impacts with qualitative assessment of non-quantifiable behaviour.
13. One relatively visible aspect of the 'output' from university research is publication in the form of academic books and journal articles, while citations provide a measure of the impact of those publications on the scientific community. The UK scores relatively well in terms of such bibliometric indicators.
14. Data on the downloads of UK articles reveal strong cross-sector knowledge flows, while data on institutional affiliations of authors show substantial mobility of authors between sectors, almost certainly transferring tacit knowledge with them.
15. Surveys of UK academics provide evidence of their involvement in a variety of impact pathways, in particular conferences, joint research projects and contract research. Most engage in one or two types of impact pathway with industry, and the level of engagement with industry has been rising as the barriers to engagement have declined.
16. Outside the STEM subjects, only a relatively small proportion of academics have been involved in 'narrower' forms of commercialisation such as patenting, licensing or forming a spin-out company. In general, far more have engaged in wider or 'softer' people-based forms of interactions such as consultancy, attending meetings, giving talks, and helping with problem-solving.
17. Surveys of firms involved in collaborative research with universities likewise reveal a wide variety of forms of engagement, including attending conferences, recruiting university graduates, student placements, contract research, consultancy, training of company staff, and creation of physical facilities. Reasons for such engagement included obtaining access to state-of-the-art research (with publications being particularly important in this respect), to problem-solving skills and to R&D facilities.



18. Among the barriers encountered by firms in interacting with universities, over half cited rules and regulations imposed by universities and governments in relation to confidentiality, intellectual property and the role of technology transfer offices (TTOs). According to the firms, such problems had seemingly become twice as common between surveys in 2004 and 2008, perhaps reflecting a policy over-emphasis on formal technology transfer and the rise of professionalised TTOs with unrealistic expectations about the economic value of research.
19. Other industrial surveys show that the business sector itself is the most frequently cited source of knowledge for innovation, followed by knowledge drawn from clients or customers, suppliers or competitors. Hence, in estimating the impact of universities, it is essential to consider them as part of a wider innovation system and not to over-emphasise the role that they may play independently in the innovation- and productivity-enhancing process.
20. However, although the business sector itself is the most frequently used source of knowledge, this knowledge is hardly ever used in isolation, with most firms also drawing upon various intermediary bodies as well as the science base. Rather worryingly, UK businesses are less likely than their US counterparts to commit the necessary resources required for effective interactions with universities. Alternatively, they may spread their resources too thinly across too many links.
21. This problem is aggravated by the fact that many UK academics feel they lack the time and resources needed to support their interactions with business. Other problems they experience include inadequate incentives and rewards for such interactions (career progression is still linked primarily to research publications rather than engagement with users), and bureaucracy or inflexibility on the part of university administrators.
22. Although capturing only a certain part of 'impact', it is significant that data from surveys such as HE-BCIS show significant increases in the numbers of patents applied for and granted to UK universities, and in the numbers of spin-offs established, including those surviving three or more years.
23. With regard to spin-offs (and indeed to most impact pathways), the impacts are extremely skewed towards just a handful of highly successful cases. It is also significant that the great majority of the most successful spin-outs had their origins in basic rather than applied research. The average research investment per university spin-off in the UK appears to be less than half the equivalent figure in the US.
24. The income from different external pathways to impact more than tripled in real terms between 2001 and 2010, showing that external users have become more willing to pay for access to university services, inputs and facilities. Most important of the pathways were contract research and collaborative research, followed by continuing professional development and continuing education. Intellectual property was the least important source of income, accounting for just 2-3% of income.
25. One of the most important pathways to impact is through the movement of people. This has been recognised in long-running support in the UK for the Teaching Company Scheme (TCS), which was launched in 1975 and is now called the Knowledge Transfer Partnership (KTP). Over 5,000 partnerships have been supported under this scheme, with around 90% of partnerships

involving businesses employing fewer than 250 employees. It is also reflected in the substantial salary premiums paid to Science and Engineering based PhDs and high qualitative assessments made by employers of their contribution to business performance.

26. An evaluation in 2002 found that approximately two-thirds of the companies involved believed that the technical objectives of their partnerships were fully or almost fully achieved, while around 40% stated that the commercial objectives had also been met. However, the economic gains were again highly skewed, particularly with regard to 'narrower' benefits in the form of improved sales, employment or profitability.
27. The wider 'softer' benefits in the form of enhanced skills and knowledge and embedding capacity in the partner firms were also very substantial. This is reflected in the fact that 62% of the company partners subsequently offered the associate a permanent post, with 84% of those individuals offered such a post accepting it. The KTP scheme reinforces the view that an important pathway to impact is through the movement of people, with the evidence suggesting that the contribution of UK universities through this particular route is significant.
28. A subsequent review of the KTP scheme in 2010 reached similar positive conclusions. It estimated that over 5,500 net additional jobs had been created by the partnerships supported between 2001-2 and 2007-8, along with approximately £4.5 billion of new sales for company partners and over £1.6 billion in terms of gross value added. Return on investment in the scheme was estimated at some £5 net additional gross value added per £1 invested by the sponsors.
29. Since 2004, the Technology Strategy Board has funded collaborative research and development projects with the aim of encouraging greater collaboration between businesses and academia and thereby raising levels of innovative activity. A 2011 evaluation estimated that these projects had generated a total of over 13,000 net additional full-time-equivalent jobs and net additional gross value added of £2.9 billion. For each £1 of grant, the equivalent increase in gross value added was approximately £6.70.
30. Between 2001 and 2011, HEFCE/OSI funding for knowledge exchange and the promotion of impact was channelled through the Higher Education Innovation Fund. A 2010 study estimated that 30-40% of knowledge exchange income could be attributed to such funding, and that the injection of just under £600 million through HEIF over 2001-07 generated between £3-4 billion in gross additional knowledge exchange income, corresponding to a gross additional impact factor of nearly 5. In addition, a large range of other non-quantifiable impacts were identified.
31. There is over 50 years of literature attempting to account for the role of research and development and of technological innovation in economic growth and productivity. In the last 20 years, there have been many studies based on endogenous growth theory, which have attributed a large positive contribution from university or publicly funded research to innovative activities and growth at the level of the economy as a whole.
32. A major study in 2004 of 15 OECD economies found that the responsiveness of economic productivity to public sector research is positive and significantly higher than the response to private sector research (0.17 compared to 0.13), perhaps reflecting the fact that publicly funded

research is more concerned with basic research and hence is associated with a higher degree of spillovers in the rest of the economy than private R&D.

33. This study also showed that the responsiveness of multi-factor productivity to public sector research is greater when business R&D intensity in the economy is higher, emphasising the complementarity of investment in the business sector noted earlier. Without such investment and its implications for absorptive capacity, the ability of the private sector to capitalise on opportunities arising from public sector research will inevitably be limited.
34. In addition, the impact of public sector R&D is positively affected by the proportion accounted for by university research (this is not the case for public sector laboratory research). Furthermore, the higher the share of university research financed by the business sector, the *smaller* is the impact of higher education R&D on productivity growth, perhaps because such research is more oriented towards the applied end and therefore less likely to yield longer-term spillover effects at the level of the economy as a whole.
35. A recent 2010 study confirms that the benefits from private sector R&D are essentially captured by the firms carrying out the research, while there are substantial positive spillover effects for research council-funded research, although the marginal effect of research council funding has declined as funding levels have risen over later years.
36. Another long-standing literature is that examining whether public and private sector R&D are complementary or tend to substitute for one another. While earlier reviews were ambiguous, more recent studies provide evidence consistent with a positive impact of public sector R&D on private sector R&D. For example, one study demonstrated that public research is critical to industrial R&D in a small number of industries but also has important effects across a much wider range of manufacturing sector R&D.
37. Another study shows that non-business R&D as a whole and business funding of non-business R&D both have a positive influence on business R&D intensity at the economy level as well as on patenting performance. This strongly reinforces the hypothesis of complementarity between business and public sector R&D.
38. A third study in this vein concludes that higher education expenditure on R&D has a positive impact on private sector R&D and on the number of R&D personnel employed in the business sector. However, this study also suggests that the UK's performance in terms of efficiency in converting public support for R&D into economy-wide performance with regard to innovation and patenting places it only in a mid-level position compared to other advanced nations.
39. With regard to studies focussing on the evaluation of research impact in specific sectors, many of the more recent ones have focused on the economic benefits of biomedical and health research. Evaluations carried out in the US and Australia have claimed to find 'exceptional returns' from biomedical research, typically of between three and eightfold, depending on the area of medical research. Indeed, one study claimed that "every \$1 of federal ... investment has contributed to the generation of \$141 in the economy".
40. However, a fundamental limitation with such approaches is the problem of attribution. None of the claimed economic benefits identified in such studies flow *solely* from the initial biomedical

research – there are numerous other contributing factors. Identifying exactly what proportion of the ultimate economic benefit should be attributed to the earlier biomedical research involves making a number of truly heroic assumptions that are open to challenge.

41. Hence, various alternative and wider ranging approaches have been proposed. These use the ‘payback framework’ and other ‘bottom-up’ tracking techniques to assess impact, acknowledging the inherent complexity of innovation pathways and the multiple complementary investments required.
42. One such study found that, of total UK health care improvements in cardiovascular medicine, between 10% and 25% could be attributed to UK public and charitably funded research with a central estimate of 17%, and with an estimated time-lag of between 10 and 25 years before the improvements came through. The direct healthcare benefits produced an internal rate of return of 9%, and an estimated overall rate of return to the economy of nearly 40% once wider effects through, for example, the stimulation of private sector research and knowledge spillovers into other areas were taken into account. Similar positive findings have been obtained in Australia, Canada and Ireland.
43. UK Research Councils have also carried out a number of evaluations of individual projects, programmes and research centres. In particular, the ESRC has conducted assessments of several of its centres. These generally combine qualitative and quantitative approaches, with interviews featuring prominently among the former.
44. While a few ESRC evaluations have attempted to place an economic value of the impact of the research, most have concluded that this is impossible, not least because of the complex non-linear process through which policy and practice are related. Consequently, there are major difficulties in establishing unambiguous links between the activities of a centre and particular policy changes, not to mention the difficulties in assessing whether the policy itself yielded net economic benefits.
45. Nevertheless, there are many instances where there is qualitative evidence of particular economic or social research having an impact on a specific policy. Various forms of impact can be distinguished, including instrumental, conceptual and empirical. Often, the impact is mediated through organisations such as think-tanks and lobby groups, making the task of ascribing impact even harder.
46. EPSRC has also commissioned impact assessments. For example, an evaluation of its Innovative Manufacturing Research Centres, after making a number of debateable assumptions, concluded that the net impact was between 5 and 13 times the initial EPSRC investment.
47. Among the main conclusions to emerge from this review, one is that, in attempting to assess the impact of publicly funded research, one needs to bear in mind that the exploitation of publicly funded research often depends on private sector capacities and investments, factors outside the control of the publicly funded researcher. Consequently, the issue is less about assessing the impact of publicly funded research per se, and more about understanding and managing connections between public and private sector in a *system* of knowledge production and innovation.

48. A second is that there are various channels or 'pathways to impact' through which research in the university base may contribute to innovation. Some of these channels are more amenable to quantitative assessment of impact, others less so although these may be at least as important. Over-emphasis by policy-makers on the more readily measurable or more immediate forms of impact (e.g. patents) may be counterproductive to research impact in the long term.
49. Thirdly, although some studies have attempted to come up with a quantitative measure of economic impact or rate of return, this has inevitably involved making a host of simplifying but questionable assumptions, in particular with regard to what proportion of a particular benefit should be attributed to publicly funded research as opposed to all the other factors involved. Moreover, such studies have revealed that benefits and impact are very heavily skewed towards just a few, highly successful cases, often for reasons well outside the control of academic researchers.
50. Fourthly, in recent years, a number of alternative and wider ranging approaches to assessing research impact have been developed such as the 'payback framework'. These start from a recognition of the complexity of impact pathways and the multiple complementary investments required. Such studies, too, find convincing evidence of substantial paybacks in a variety of forms for publicly funded research.



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## 1. Introduction

This report provides a review of evidence relating to the impact of public sector research and development (R&D) on economic performance, both at the macro-economic level as well as at the level of individual sectors. The relevant literature is very large, having grown rapidly in recent years, and it has been the subject of several reviews (e.g. Martin et al., 1996; Salter et al., 2000; Salter and Martin, 2001; Scott et al., 2002, Martin and Tang, 2006). Our primary focus is on the UK and on more recent evidence.<sup>1</sup>

The UK public sector influences R&D expenditure in several ways. First, the public sector itself carries out research in various departments of state. Secondly, it provides funding to directly support R&D carried out elsewhere in the economy. For example, it funds R&D carried out in the Higher Education Sector via the Higher Education Funding Councils and the Research Councils (through the 'Dual Support' system). It also, through grants and contracts, funds R&D expenditure carried out in the private business and not-for-profit sectors. Thirdly, it provides indirect support through fiscal incentives to the private business sector principally in the form of R&D tax credits. Our focus in this review will be on the second of these routes and in particular on the role of publicly funded research in the higher education sector.

The allocation of public sector funding for university research in the UK is increasingly conditioned by the need to demonstrate 'impact'. The impact imperative is reflected in both parts of the dual funding structure of the UK higher education system. Competitive bidding for grants through the Research Councils requires the identification of impact pathways during the grant application process. It also involves the identification of impacts beyond peer group research publications in the post-project evaluation process (Research Council Economic Impact Group ('Warry Report'), 2006). Since 2011, each of the Research Councils has been required to produce an annual impact report and a set of standard impact indicators (AHRC, 2011; ESRC, 2011; EPSRC, 2011b; BBSRC, 2011; NERC, 2011; STFC, 2011; RCUK, 2011; MRC; 2011).<sup>2</sup> Similarly, the Funding Councils' Research Excellence Framework assessment exercise in 2013 will, for the first time, include an assessment of wider socio-

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<sup>1</sup> We do not discuss the overall rationale for public sector support for R&D. The arguments from both a 'market failure' and 'innovation systems failure' point of view are well known and have been reviewed extensively elsewhere. Annex 2 sets out a brief overview of the key concepts.

<sup>2</sup> It has been estimated that between 2000 and 2010 the UK research councils produced 96 documents dealing with impact, of which 35 were impact studies and 19 internal evaluation reports (de Campos, 2010, Table 3).

economic impact beyond the strictly academic. This will be based on sets of case-study submissions<sup>3</sup> (HEFCE, 2011a).

We provide in the next section a brief overview of the scale of public sector R&D in the UK. This is done in terms of both the funding and conduct of R&D and the way that role has evolved in the recent past. It places university research funding in the context of the UK R&D system and discusses the breakdown behind applied and basic research. The next section sets out an innovation systems framework for assessing the impact of public funded R&D and is followed by a section reviewing studies on impact with a particular focus on the UK. A final section summarises the main conclusions.

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<sup>3</sup> At the same time that these developments have occurred, there has been an increased interest in the role that the public sector can play by the way it chooses to procure R&D services from the private sector, and in the way it organises its own departmental research programmes and the work of government laboratories. This is an important issue which needs to be addressed separately.

## 2. Public Sector Support for Research Activity in the UK

### 2.1 Overview

The UK public sector both funds and carries out R&D. Exhibit 1 uses the ONS data to provide an overview for 2010 of the overall pattern of funding and carrying out R&D in the UK. The exhibit is based on the official sectoral categorisation of the UK R&D data. This categorisation separates out the Government from the Research Councils and the Higher Education Funding Councils, as well as the higher education sector and the not-for-profit sector. It also shows funding from abroad and R&D funded abroad as well as a breakdown of overall R&D spend and funding for civil and defence purposes. It is important to note that the Research Councils and the Higher Education Councils appear as 'funders' in this table as well as performers of research. The resources they allocate as 'funders' is, however, overwhelmingly dependent upon budgets provided by the government as part of the budgetary and spending review process. The role of the public sector as a funder is therefore captured by the first three rows. The government has direct control over the allocations in the first row. It also controls the overall total budgets for public sector funds to be disbursed by the Research Councils and the Funding Councils in the second and third rows.

Row 1 shows that the government carries out and itself funds just over £1 billion worth of R&D. It also funds around £1.4 billion of R&D carried out by the private business enterprise sector. In addition, it funds smaller amounts carried out by the laboratories of research councils and similar bodies in the not-for-profit sector. Out of the total UK R&D expenditure of £26.4 billion, it directly funds £3.3 billion across all R&D-performing sectors taken together (including itself) and indirectly a further £2.9 billion through the research councils and £2.3bn through the Funding Councils. Thus directly or indirectly the public sector funds £8.5 billion worth of R&D, which is around 32% of the total UK R&D spend. By contrast the private business sector carries out just over £16 billion of R&D, of which it funds around £11 billion itself and attracts around £3.6 billion of funding from abroad and £1.4 billion from the government.

### Exhibit 1 R&D Performed in the UK in 2010 by Performing Sector and Source of Funds (£millions)

SECTOR PERFORMING R&D									
	Government	Research Councils	Higher Education	Business Enterprise	Private/ Not-for-Profit	TOTAL	Abroad	Civil	Defence
*SOURCE OF FUNDING	Government	94	516	1,390	171	3,262	338	2,030	1,232
	Research Councils	33	1,948	3	93	2,944	338	2,944	0
	Funding Councils	0	2,303	na	na	2,303	na	2,303	0
	Higher Education	1	298	0	10	326	na	325	0
	Business Enterprise	156	293	11,075	58	11,612	2,429	11,120	492
	Private Not-for-Profit	6	74	968	5	1,269	na	1,269	0
	Abroad	85	57	804	3,594	107	4,646	na	213
	TOTAL	1,371	1,141	7,130	16,067	653	26,362		
Civil	1,146	1,141	7,092	14,394	652	24,425			
Defence	225	0	38	1,673	1	1,937			

Source: Calculated from Office of National Statistics UK. Gross Domestic Expenditure on Research and Development (2010).

Note: n.a. means data not available or insignificant amount. Columns may not exactly sum due to rounding.

\*The Official Statistics identify the Research Councils and Funding Councils as 'fundlers' of research since they award or allocate funding to those performing R&D in the Higher Education sector and the Research Councils' own research facilities. The core source of the funds they allocate is government. The shaded area therefore represents total public sector funded research carried out in UK non-government department public science base.

The exhibit shows that £7.1 billion of R&D or around 27% of total R&D is carried out by the higher education sector. Of that total, £4.7 billion is funded directly by government or indirectly through the Research and Funding Councils, with the remainder funded principally from overseas or not-for-profit sources. UK business enterprise is a much smaller funder than these sources.

## **2.2 UK Government Expenditure on Higher Education R&D in the UK**

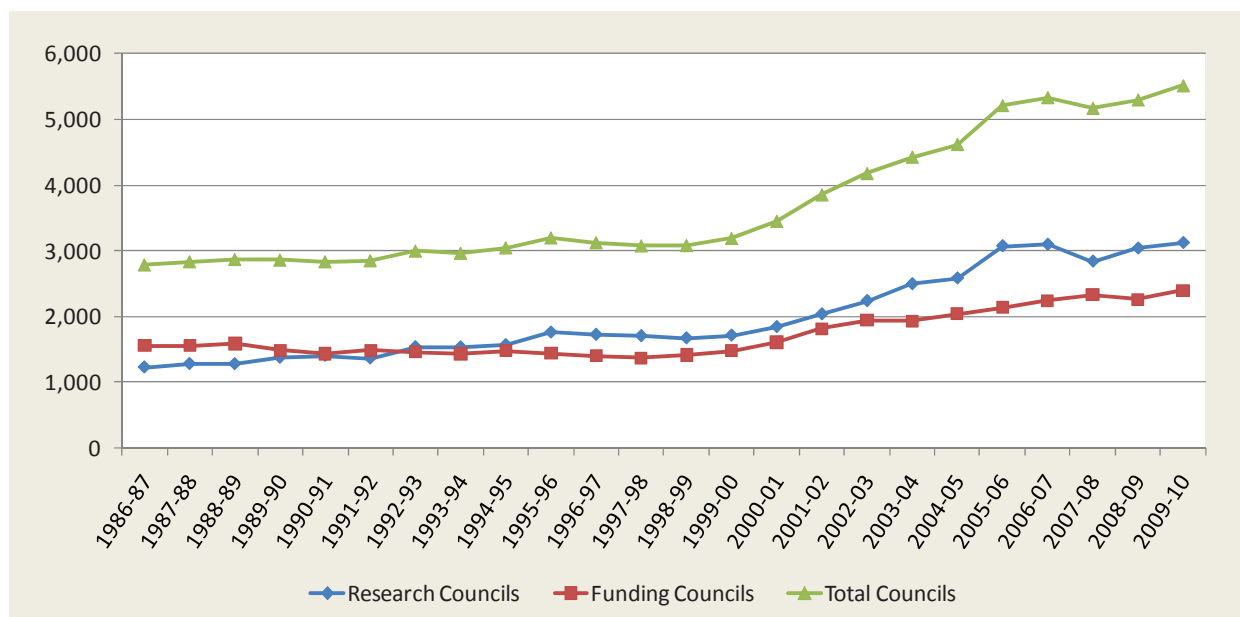
Exhibit 2 sets out trends in government support for university R&D through the dual support system. This reveals a striking upward trend in real terms.<sup>4</sup> From the late 1980s onwards, increases in expenditure in support of the Research Councils by the government have outstripped the rate of growth of expenditure allocated through the Funding Councils. Thus whereas in 1986/7 government expenditure on the Funding Councils exceeded that on the Research Councils, the reverse is true by 2009/10. The Research Council stream has increased by approximately 50% in real terms in the period 2001-2010. It is important to note, however, that these shifts in government expenditure on R&D through the Higher Education Funding Councils and the Research Councils have been affected by the introduction of full economic costing of research activities in UK universities. This has meant that at least part of the increase in government expenditure under these headings is accounted for by an increase in the 'cost' of the research carried out with funding from these expenditure streams, rather than necessarily an increase in the volume of research carried out. Indeed the changes were introduced on the basis that they would not increase the volume of research but rather ensure that the volume carried out was funded to more fully reflect indirect as well as direct costs and thus avoid university deficits on research funding.<sup>5</sup>

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<sup>4</sup> In contrast to the trends in expenditure by the government through the Research Councils and the Funding Councils, there has been a long-term downward trend in real net expenditure on R&D carried out by the government itself. This is primarily due to falls in defence R&D, which has not been offset by developments in civil R&D expenditures. Defence expenditure, of which the bulk is development expenditure rather than research per se, has fallen substantially in real terms from £4.7 billion in 1986/7 to £1.7 billion in 2009/10. Expenditure by civil departments in real terms is £200 million higher in 2009/10 than it was in 1986/7 and has therefore changed little. (For further discussion of R&D trends over time and in an international context, see Hughes and Mina, 2012).

<sup>5</sup> As a result of the introduction of Full Economic Costing (FEC), research costs rose to reflect a more appropriate level of overheads. A succession of awards were made by government to the Research Councils to enable them to meet the higher costs of research grants budgeted on a Full Economic Cost basis. Thus there was an award rising to £200 million in 2007/8 to the research councils to provide 80% full Economic Cost payments. Moreover, the 2008 comprehensive spending review confirmed further planned uplifts of £187 million for 2008/9, £274 million for 2009/10 and £316 million for 2010/11. The assumption behind the provision of this additional funding was that it would contribute towards the full cost of research, but the volume of research would remain reasonably constant (see, for example, Alexander, 2009, p.10, and the discussion in Wakeham, 2010).

**Exhibit 2 Real Net Government Expenditure on R&D: Research and Funding Councils  
(£ million 2009-10 prices)**



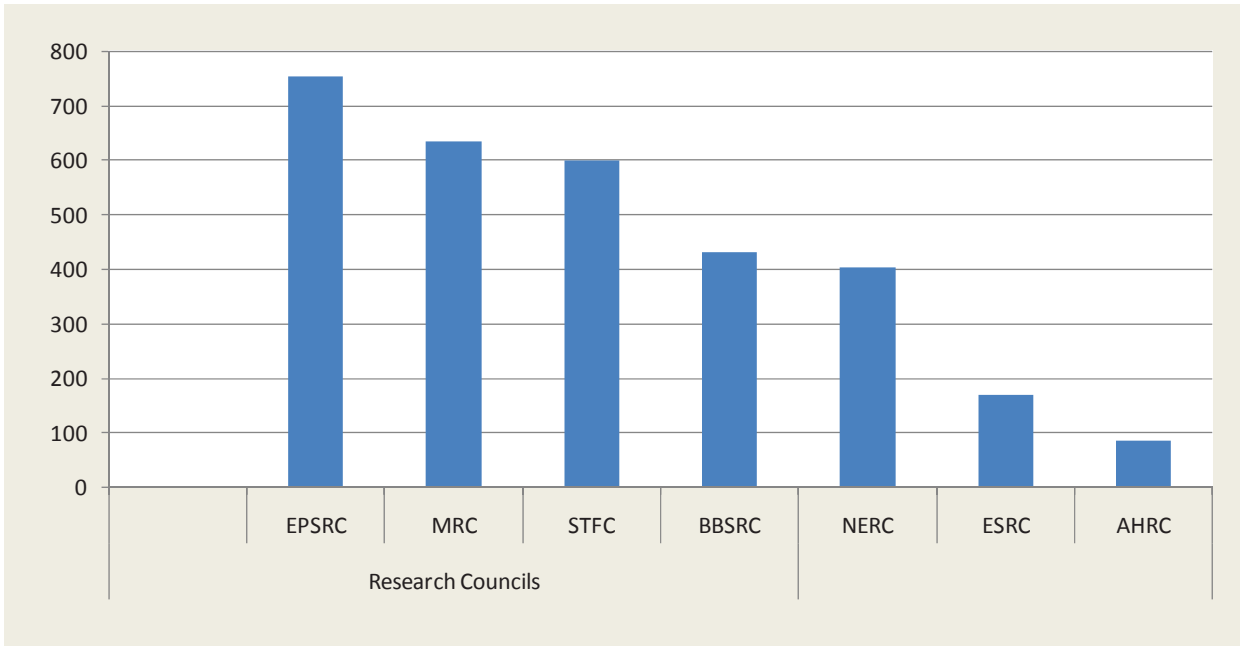
Source: BIS SET Statistics: Science Engineering and Technology Indicators (2011, Tables 2.2 and A2.2).

These changes have not surprisingly led to increased interest in the impact of the growth in real expenditure in support of Higher Education R&D.<sup>6</sup>

The distribution of government expenditure on R&D by the Research Councils is shown in Exhibit 3.

<sup>6</sup> This is reflected for example in the introduction of standardised metrics in the annual impact reports of the Research Councils and the publication of guides to impact pathways on their websites and that of RCUK. At the same time there has been increasing emphasis on how best to maximise the impact of a falling expenditure pattern in real terms with regard to the government’s own R&D. This has led to a focus on identifying government departments, in particular health and defence, which have a critical mass of expenditure to exert leverage, for example via purchasing R&D services.

### Exhibit 3 Government Net Expenditure on R&D by Research Council 2009-10 (£million)



Source: BIS SET Statistics: Science Engineering and Technology Indicators (2011, Table 2.3).

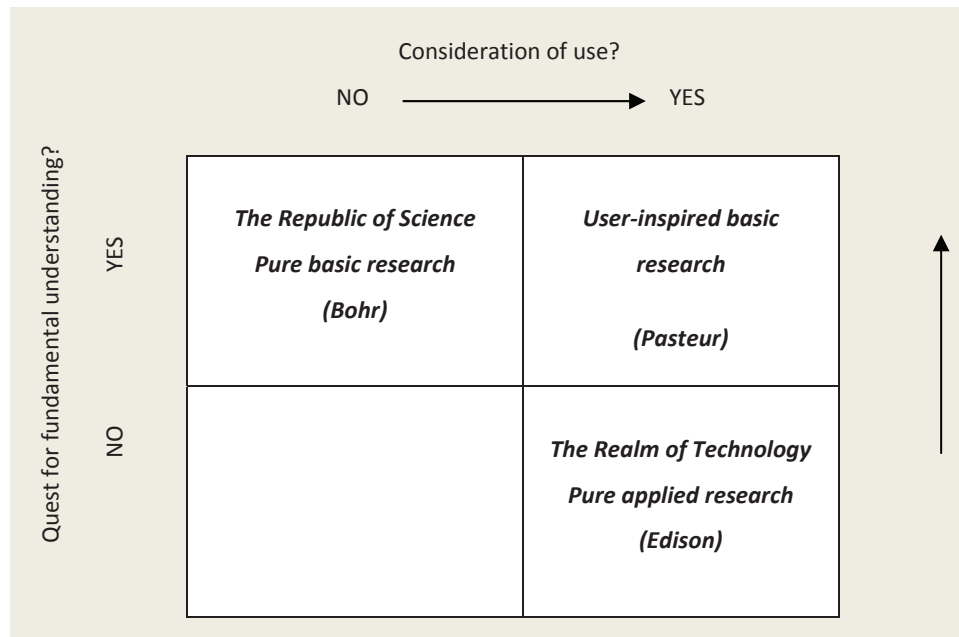
The expenditures through the Engineering and Physical Sciences Research Council, the Medical Research Council and the Scientific and Technical Facilities Council dominate the budgets followed by the Biological and Biotechnology Science Research Council and the Natural Environment Research Council. Social Sciences and the Arts and Humanities make up the balance of research funding through the Research Councils. In terms of potential impacts, it is clear that the great bulk of university research support from this component of the dual funding structure is focused on science and technology.

### 2.3 Public Sector Support for Basic and Applied Research

Debates over the potential impact of publicly funded research have been concerned with its form as much as its amount, and in particular that an emphasis on impact will threaten basic research commitments in favour of an emphasis on applied research (Hughes; 2011). Evidence on this division is confounded by difficulties regarding the distinction between ‘basic’ and ‘applied’, and by questions as to the usefulness of the distinction in suggesting a trade-off or substitution relationship between them.

There is extensive evidence suggesting a fruitful interplay between applied and basic research existing within a university context, and the two should be seen as complementary rather than competitive. The point was well made by Donald Stokes (1997) in his ‘quadrant’ representation of different forms of research (reproduced as Exhibit 4 below).

#### Exhibit 4 Stokes’s Quadrants



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

This characterises the *motivation* for research in terms of either the quest for fundamental understanding or activity motivated by considerations of use or application. As Stokes and others have pointed out, many fundamental scientific advances were driven by an initial concern with tackling some problem arising from considerations of use. Thus, in Stokes’s Quadrants Diagram we find three types of research activities identified. Pure basic research is concerned only with the fundamental understanding and is represented by Bohr’s Quadrant (also labelled here, following Dasgupta and David, 1994, as the Republic of Science). Applied research is solely motivated by considerations of use and is represented by Edison’s Quadrant (or, following David and Dasgupta, the Realm of Technology, in which private sector R&D may be expected to be dominant). Research driven both by consideration of use and by the quest for fundamental understanding is represented



by Pasteur's Quadrant. A substantial portion of publicly funded research may therefore lie in Pasteur's Quadrant, while individuals and research groups may move between quadrants in the course of research projects.<sup>7</sup> Ignoring this category of Pasteur's Quadrant to focus solely on notions of 'pure', basic or applied research will therefore overlook a key element in actual research practice and an important point of contact between public and private sector research activity.

The OECD currently offers the following definitions of basic and applied research, to guide national data collection.<sup>8</sup>

Pure basic research is carried out for the advancement of knowledge, without working for long-term economic or social benefits and with no positive efforts being made to apply the results to practical problems or to transfer the results to sectors responsible for its application.

Oriented basic research is research carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognised or expected current or future problems or possibilities.

Applied research is original investigation undertaken in order to acquire knowledge. It is, however, directed primarily towards a specific practical aim or objective.

(OECD, 2012)

Experimental development is systematic work which draws on existing knowledge. It is directed to producing new materials, products processes, systems and services, or to improving the performance of existing ones.

In the case of UK data collection and analysis, applied research has been further divided into strategic (knowledge that has not yet advanced to the stage that a specific application can be specified) and specific (when an application has been identified). As a first approximation, we might consider oriented basic research as falling into Pasteur's Quadrant.

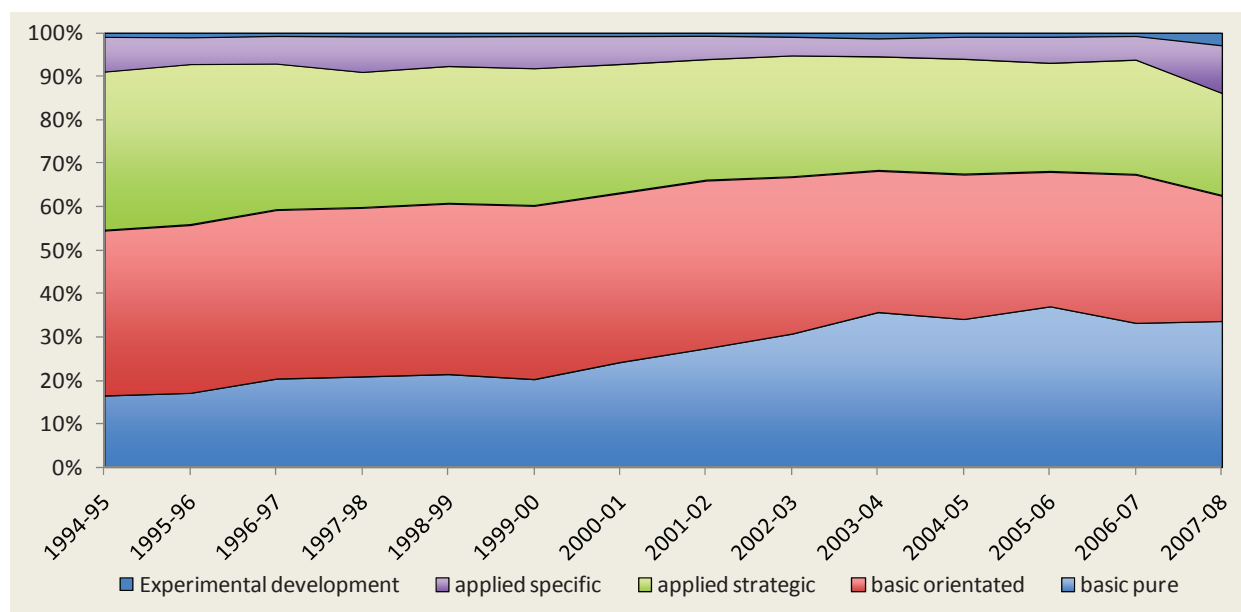
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<sup>7</sup> There is also recent evidence that academics consider themselves as carrying out projects which combine elements of basic research, applied research and experimental development, although the proportions of each vary across subjects. Thus, the natural sciences and humanities are more likely to report basic research as a large component of their research activities, whilst social scientists, medical researchers and technologists are less likely to do so (Gulbrandsen and Kyvig, 2010).

<sup>8</sup> Tracking actual research activity in terms of these distinctions is not straightforward. See OECD (2002) for a fuller discussion of the classifications and their definitions, and Calvert and Martin (2001) and Godin (2005) for a discussion of the interpretation and evolution of these definitions.

Exhibit 5 shows (for the UK Research Councils) trends in the share of basic pure and basic oriented research, as well as applied strategic research, and applied specific research. It also shows experimental development. The data are shown for the period from 1994-5 to 2007-8 (which is the last year for which data on this series were published).<sup>9</sup>

**Exhibit 5 The Distribution of UK Research Council Funding between Basic and Applied Research 1994-2008.**



Source: BIS SET Statistics: Science Engineering and Technology Indicators various editions.

Exhibit 5 shows a rising share of pure basic research for the ten years after 1994-5 followed by relative stability after 2003-4. With the exception of a rise in the share of applied specific research in the last year of the series (at the expense of oriented basic research and strategic applied research), the spread across categories has remained broadly stable since 2003-4. It does not appear that ‘pure’ basic research has suffered as a result of recent trends in research council funding. Experimental development is, as might be expected, a relatively insignificant component of research council funding. Unfortunately, there is no comparable published breakdown of research funded by the Funding Councils.

<sup>9</sup> The breakdown is not consistently available for UK prior to 1994-5. For a discussion of the evolution of data for the UK, see Godin (2005).

In 2007/8 the percentages of research council funding accounted for by each category were Basic 62.6% (Pure Basic 33.7%, Oriented Basic 28.9%), Applied 34.6% (Applied Strategic 23.6%, Applied Specific 11.0%) and Experimental R&D 2.8%.<sup>10</sup>

In view of the difficulties of classifying research funding from government statistical sources and since the underlying Stokes' Quadrant classification is driven by motivational considerations, it is useful to consider the spectrum of applied to basic motivations that emerges when academics are themselves asked to classify their research activities.

Exhibit 6 summarises the results of a recent national survey of academics relating to this point covering the years 2006-9. It shows the self-classification of that subset of the whole sample reporting that they held a research council grant.

The surveyed academics covering all disciplines and all UK universities were asked the following questions:

- If undertaking research, which of the following statements most closely describes it?
- Basic research: theoretical, empirical or experimental work, undertaken primarily to acquire new knowledge about the underlying foundation of phenomena or observable facts, without any particular application or use in view.
- User-inspired basic research: theoretical, empirical or experimental work, undertaken primarily to acquire new knowledge about the underlying foundation of phenomena or observable facts, but also inspired by considerations of use.
- Applied research: original investigation undertaken in order to acquire new knowledge directed towards an individual, group or societal need or use.
- None of the above apply to my research.

Exhibit 6 shows that, of individuals surveyed, 56.2% classified themselves as concerned with Basic Research, of which 34.9% fell into the User-inspired or Oriented Basic Research Group (Pasteur's Quadrant), and 43.9% classified themselves as applied. The pure basic portion was highest in Arts and Humanities and lowest in Economic and Social Research. The Oriented or User-inspired Basic research was, however, much more similar across councils. Comparisons with the expenditure data are not straightforward since it would be necessary to weight each academic respondent by the value of the grant support. Nonetheless the data are included as the last row in Exhibit 6. They

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<sup>10</sup> The series is no longer published because of concerns about its reliability (ONS communication with the authors).

reveal that academics are less likely to believe they are motivated by purely basic and more by applied considerations than the expenditure classification suggests. What is striking from both the expenditure data and the academic survey data is the substantial weight in both given to research that falls into the Pasteur Quadrant. This belies the idea of a simple basic-applied dichotomy for use in either policy development or potential impact terms.

### **Exhibit 6 Classification of Research Activity 2006-9 by UK Research Council Holders (% Respondents)**

	Pure Basic research %	Oriented or User-inspired basic research %	Applied research %	Total respondents N
Arts and Humanities Research Council (AHRC)	35.0	33.6	31.4	789
Economic and Social Research Council (ESRC)	15.8	35.9	48.3	1,686
Science Research Councils such as BBSRC, EPSRC, MRC, NERC, STFC	19.9	35.1	44.9	3,168
Any Research Council	21.2	34.9	43.9	5,168
Share of Research Council Funding 2007-8	33.7	28.9	34.6	

The exhibit excludes the very small number that ticked 'None of the above apply to my research'.

Source: Calculated from data in Hughes et al. (2010a) and Exhibit 4.

## **2.4 Assessing the Impact of Publicly Funded Research: Conceptual Issues**

From an innovation systems perspective, the impact of publicly funded research will be substantially affected by the capacity of other actors in the economic and innovation system to access, understand and use the research outputs produced with public sector support. This depends to a considerable extent on the R&D that the private sector itself carries out. R&D activity in the private sector has two purposes or 'faces'; it creates new knowledge in itself but it also enhances the firm's 'absorptive capacity' – i.e. the ability of a firm to identify, understand and exploit knowledge developed elsewhere in the innovation system, including in the public sector (Cohen and Levinthal, 1989 and 1990).

Private sector research and the publicly funded research base therefore represent two complementary systems of activity, in the sense that each is specialised in a particular aspect of the innovation system (Foray and Lissoni, 2009).

“Universities are not organized and governed to be producers of innovations in their own right – they are first and foremost designed to achieve a new understanding of natural phenomena and technologies: in this task they are naturally *inventive*. Conversely, in modern free market economies, it is firms that have the incentives and governance structures to make innovation their central goal, and are expected to be the almost exclusive sources of *innovation*. In the realm of innovation, a public research organization will never be more than a second rank institution” (ibid., p 11; emphasis added).

From this perspective, therefore, the central policy concern is not the relative impact of one expenditure form to another. Instead, it is a classic systems problem, namely how best to manage the boundaries between these two relatively specialised organisational forms so as not to damage the role played by each other. There is a potential institutional systems failure relating to potentially different norms and motivations in these two organisational forms. This is the problem of

“managing a trade-off between two good things: getting more academic knowledge used by the economy versus maintaining the fundamental missions (long-term research and education) of universities” (Foray and Lissoni, 2009, p13).

Seen from this perspective, the issue is not about isolating the impact of publicly funded research per se or about determining its optimal level in isolation. It is instead about analysing how best to understand and manage connections between differently funded and motivated research efforts in a *system* of knowledge production and innovation (Metcalfe, 2010).<sup>11</sup> In the context of the Stokes’ quadrant analysis, it is important to emphasise that this is only part of the story. The impact of publicly funded research depends not only on understanding transitional pathways, but also involves examining the ways that scientists are motivated or influenced by problems and areas of research stimulated by interactions through these pathways. Impact involves both the presence and effectiveness of the mechanisms or pathways by which knowledge is exchanged and connections are made, but also the extent to which the nature of the pathways or connections between the public and private sector domains influences the direction and nature of research in the former [See Box 1].

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<sup>11</sup> It is important to note, however, that although this specialization argument may be a useful research heuristic, it does not necessarily reflect the historical evolution of university interest in applications. In both the UK and elsewhere in Europe, the design and organisation of university and higher education structures and their long-term missions have long involved concern with applications (Martin, 2012). There is also a danger that such a specialization view will lead to a stereotyping of the academic research to be supported by public funding as ‘basic’ whilst the private sector is concerned with ‘applied’ research. We have seen that there is good reason for believing that such a distinction is not particularly helpful.

Understanding and assessing the impact of public sector funded research requires first situating it in the wider innovation system, which will condition impact in important ways. This raises acute difficulties in assessing ‘impact’.

### **Box 1 Connections and Impact Pathways**

A series of reviews and empirical studies have identified a number of key channels or what would now be called ‘pathways to impact’ through which research in the university base may contribute to innovation. These include: increasing the stock of useful knowledge; the supply of graduates; the creation of new instrumentation or methods; the development of new networks; university-based problem-solving and contract research; the enhancement of technological problem-solving capacity; the generation of new firms; and the provision of what Salter et al. (2000) term ‘social knowledge’ (see Martin et al., 1996; Salter et al., 2000; Salter et al., 2010; Scott et al., 2002; and Hughes and Kitson, 2012).

In a similar vein, the variety of these pathways, and the need to adopt a more disaggregated approach to them, is reflected in a major review of the role of academic research with regard to industrial performance in the US (National Academy of Engineering, 2003). In a detailed study of the nature of university-industry interactions on industrial performance in five sectors\*, the authors concluded that

“numerous diverse, robust, and often mutually reinforcing vectors link academic research to industry, including direct hiring of students, graduates, and faculty; temporary exchanges of researchers; faculty consultancy; industry-sponsored research contracts and grants; research centres; consortia; industrial liaison programmes; technology licensing; start-up companies; publications; and conferences” (ibid., p.227).

They also noted that there were substantial variations in the nature of these interactions from industry to industry, and that these involved both social and natural sciences and were critically mediated by the ability of the companies in the sector to manage the interface with academic research and researchers, a result consistent with survey-based evidence for the UK and US (Hughes and Kitson, 2012; Cosh et al., 2006).

\*The industries analysed were Network Systems and Communications; Medical Devices and Equipment; Aerospace; Transportation, Distribution and Logistics; and Financial Services.

## **2.5 Assessing the Impact of Publicly Funded Research: Empirical Challenges**

Since much of the policy debate about public funding for university-based research in the UK is conducted in terms of justifying support in Treasury spending reviews, it is perhaps useful to begin by considering the UK Treasury impact model (HM Treasury, 2004 and 2011).

The Treasury has published two volumes on the principles and practice of impact evaluation. *The Green Book* (HM Treasury, 2004) focuses on the economic principles that should guide appraisal and evaluation. *The Magenta Book* (HM Treasury, 2011) provides a more in-depth guide to the way in which impact evaluations should be designed and carried out. *The Green Book* embodies the

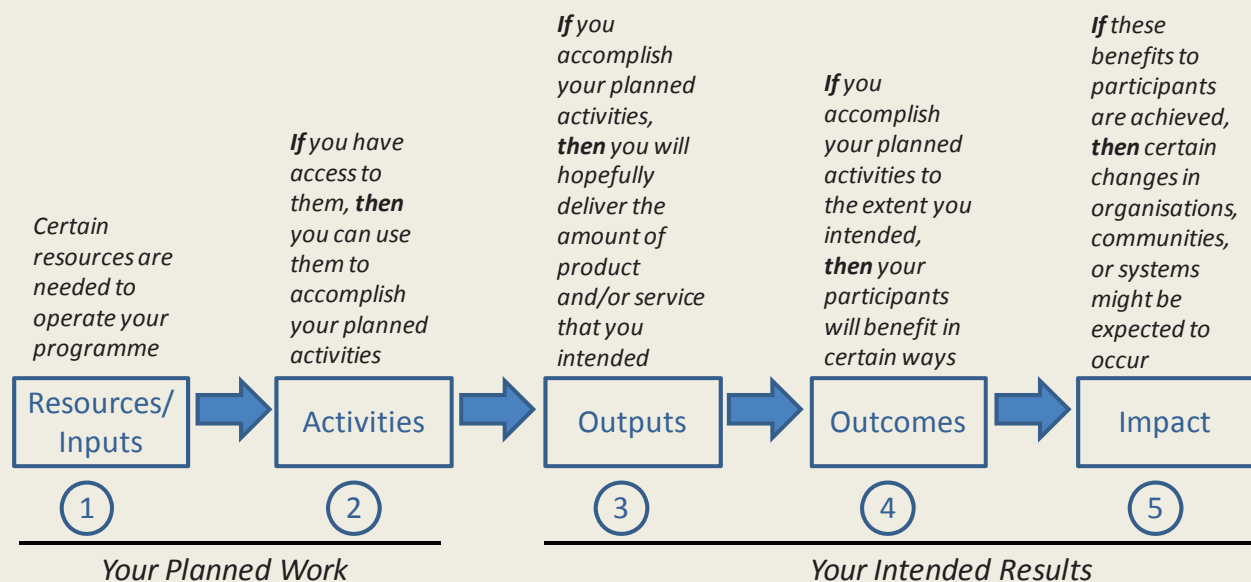
Rationale, Objectives, Appraisal, Monitoring, Evaluation and Feedback (ROAMEF) evaluation framework. This is designed to capture the whole evaluation process from policy development through to impact. *The Magenta Book* focuses on the evaluation phase. At the heart of both *The Green Book* and *The Magenta Book* lies the concept of a 'logic model'. The use of such logic models is well-established in policy evaluation for the public and charitable sectors (see e.g. Kellogg Foundation, 2004). The idea behind the Treasury logic model is to set out the links between a public policy intervention in terms of inputs, activities, outputs, outcomes and impacts (see Box 2).

### Box 2 Logic models and the terms they use

A logic model describes the theory, assumptions and evidence underlying the rationale for the programme ... "it links outcomes (both short and long-term) with programme activities/processes and the theoretical assumptions/principles of the programme".

Source: WK Kellogg Foundation (2004)

#### Kellogg Foundation Logic Model



Term	Definition	Example
Inputs	Public sector resources required to achieve the policy objectives	Resources used to deliver the policy
Activities	What is delivered on behalf of the public sector to the recipient	Provision of seminar, training, events, consultations, etc.
Outputs	What the recipient does with the resources, advice/training received, or intervention relevant to them	The number of completed training courses
Intermediate Outcomes	The intermediate outcomes of the policy produced by the recipient	Jobs created, turnover, reduced costs or training opportunities provided
Impacts	Wider economic and social outcomes	The change in personal incomes and, ultimately, wellbeing

Source: HM Treasury (2011, p.54).

Since these standard logic model terms are widely used in the public policy evaluation domain in the UK, it is useful to try to be clear about their meaning. *Inputs* are defined as the public sector resources required to achieve the policy objectives. *Activities* are the things done by those receiving the resources (e.g. carrying out a research project). *Outputs* are what the recipients produce with the resources (e.g. publications). *Outcomes*, sometimes called *intermediate outcomes*, are the changes in the actions or behaviour resulting from the outputs (e.g. more academic publications cited by public-sector policy-makers or by private-sector patent applications). Finally there are *impacts*, which are the wider economic and social effects of the policy intervention or changes in business practice (e.g. a policy change alleviating child poverty, more commercialisation of research, introduction of new drugs etc. – see for example Box 2 and HM Treasury, 2011, Table 2A, p.22).

The first four elements (inputs, activities, outputs, outcomes) are sometimes described as the *process* aspect of impact evaluation and relate to how the policy or public expenditure programme was delivered and its proximate outcomes. Whilst a great deal of the information required to examine inputs, activities and intermediate outcomes is potentially qualitative, it may include quantitative estimates, for example, of the amount of funding or the type of pathways by which changes in activities and outputs have occurred. It is important to note that these are regarded as central to measuring the success of an intervention as well as linking explicitly to the impacts (see, for example, HM Treasury, 2011, p.18). Final stage impacts are, however, seen as central to the evaluation, in which the outcomes in terms of the actions of the individuals or recipients supported by the public sector have substituted for, or displaced, activities and outcomes previously undertaken by others. This converts the gross outcomes to net or additional outcomes. It could be argued that, in terms of public sector funded research, most of the inputs and activities are likely to be additional, since the ‘basic’ nature of scientific research means that if the state did not fund it, most of it would not take place. Moreover, there is strong evidence reviewed later in this report that public sector funding is complementary to, and not a substitute for, private sector funding. The more public sector funding is concerned with ‘nearer to application’ research or the provision of outputs and impacts that might substitute for private sector activities (e.g. consultancy or training programmes), the more significant additionality issues may potentially become<sup>12</sup>. Finally, the outcomes are subject to a counterfactual test to establish to what extent the net outcomes and the process changes that have been identified would have occurred anyway without the intervention. This hypothetical counterfactual is, by definition, unobservable, and a variety of strong assumptions are usually required to make reliable estimates of it.

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<sup>12</sup> For a recent logic model and systems-based evaluation addressing these additionality issues, see Hughes et.al. (2011b) and PACEC/CBR (2009).



Finally, having obtained estimates of impact, one can translate these into cost benefit or cost effectiveness calculations by working out the monetary value of the estimated impacts and comparing them with the estimated costs of the intervention. Cost Effectiveness Analysis (CEA) essentially compares the total quantity of the direct outcome/impact generated to the cost of generating the outcome/impact, while Cost Benefit Analysis (CBA) is seen as going beyond the proximate outcomes of the policy towards wider indirect socioeconomic benefits including spillover effects outside the immediate participants in the project or programme.

It is important to note that within the Treasury Logic Model approach, whatever the final estimates of impact are, understanding why they happened is deemed to be critically important. Understanding the process by which the changes occur is singularly important because of the potential implications this has for developing particularly successful types or parts of policies and discontinuing unsuccessful components.

It is fully accepted in *The Magenta Book* approach that in certain circumstances the most appropriate evaluation method may be to restrict the scope of the evaluation to shorter, simpler links in the logic chain. This emphasises the importance of process as a guide to policy evaluation (see for example HM Treasury, 2011, p.46). The circumstances in which an empirical evaluation of the value for money, or rate of return, is deemed feasible depends upon the complex cumulative nature and scope of the public support and the possibility of identifying a counterfactual to compare the actual situation with.

If the relationship between final outcomes and the policy interventions are complex or 'distant' with many potential confounding factors, then a quantitative empirical impact evaluation is significantly less feasible. The same will be true if the effects build up gradually over an extended period of time. Similarly, impact evaluation will prove difficult where the policy or activity involved itself represents a consolidation of a range of potential policy interventions that have accumulated over time.<sup>13</sup> It is also important to note that in the view of leading research-focused businesses, requiring impact performance measured in terms of rates of return may be self-defeating anyway:

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<sup>13</sup> Martin and Tang (2006).

“because they are relatively free of the obvious business pressures that come from Return on Investment calculations, they (*academics*) can stimulate ideas that may be of great value in the long run, but which also may be honourable dead-ends.”<sup>14</sup>

CIHE 2010b p.3

Finally, if the policy is being widely applied to a class of economic actors (e.g. the whole of the university sector), then difficulties will arise in identifying suitable counterfactuals. In these circumstances the bulk of the evaluation activity will necessarily focus on process evaluation and intermediate outcomes (see, for example, HM Treasury, 2011, p.101).

Attempts to evaluate the final ‘impact’ of public sector funding of research in terms of the Treasury logic model and in particular to estimate final rates of return for public funding of research frequently encounter these problems. In these circumstances, the intrinsic value of the logic model approach lies in the theoretical basis on which it is constructed. Understanding the rationale for, and the empirical support for, links between the stages of the logic model in any public sector intervention, and the mechanisms and pathways associated with them, are of central concern. These connections form the core of the systems-based approach to policy analysis and evaluation that we adopt in this report.<sup>15</sup>

For the purposes of this report our approach may be summarised in the form of a public sector research funding logic chart.<sup>16</sup> It proceeds from activity (e.g. R&D) to outputs (e.g. research papers and outcomes of clinical trials), and impacts in terms of changes in overall productivity and performance resulting from the new product or form of treatment. Exhibit 7 sets out in schematic form this process in relation to R&D activity and embeds it in a wider systems or evolutionary context.

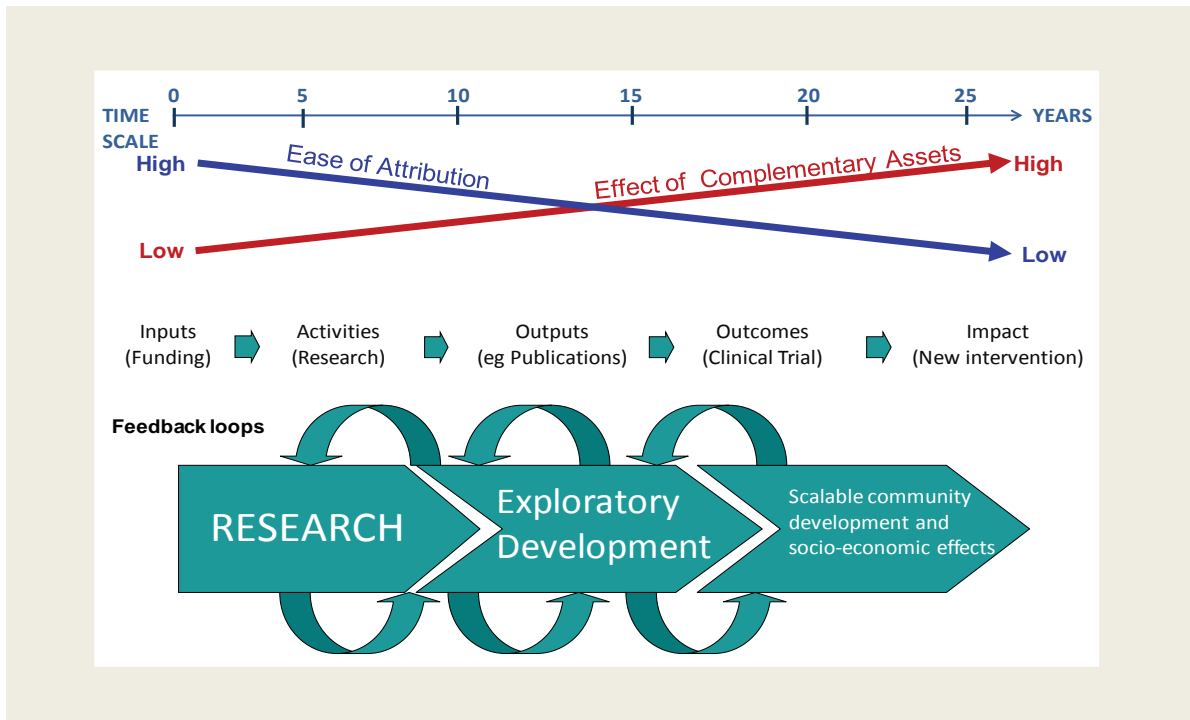
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<sup>14</sup> This is based on the views of business leaders drawn from Anglo American plc, AstraZeneca plc, BAE Systems plc, BP plc, EADS (Innovation Works), GlaxoSmithKline plc, National Grid plc, Pfizer plc, Schlumberger Cambridge Research, Syngenta, United Utilities plc, and Willis Re, “twelve global businesses who invest heavily in research and development in the United Kingdom, and across the globe, and who have long-standing and deep relationships with hundreds of universities, both domestically and internationally”(CIHE, 2010b, p.1).

<sup>15</sup> For an application of the Treasury logic model to some examples of UK Research Council Funding, see PA Consulting Group and SQW Consulting (2007). For wider recent reviews of logic models discussing the relationship between linear theory-driven and systems-based approaches and the importance of causal process interpretations, see Coryn et al. (2011) and Astbury and Leeuw (2010).

<sup>16</sup> As noted later, many other impact assessment frameworks are based on a similar logic model.

## Exhibit 7 Time, Attribution, Impact



Source: Hughes (2012).

The Treasury impact logic chart is linear in the sense that it implies an overall direction of movement from R&D inputs to eventual impact. The ellipses in the middle of the chart thus represent this logic chart transition from inputs through outputs to impact. The broad arrow in the middle indicates the transition in the main kind of research that might be assumed to take place at each of the various stages. This begins with research and runs through exploratory development to final scalable production and hence to socio-economic and community effects. At each stage, the transmission and exchange process can involve the multiple pathways set out in Box 1, pathways which may vary from sector to sector of application. Our logic chart is, however, embedded within an evolutionary innovation systems framework, so Exhibit 7 explicitly includes non-linear feedback loops between each 'stage'.

Exhibit 7 also has a time-scale across the top to indicate the period of time over which this process might take place, which may be discipline, project or sector specific. Finally, two arrows sloping upwards and downwards from the left indicate respectively (i) the increase in the importance of complementary assets to the original research activity that are necessary to get scalable and socio-economic impact (a system effect); and (ii) the corresponding decrease in the ability to attribute the final outcomes to a particular set of initial public-sector research inputs or activities (leading to a

measurement problem). Isolating and attributing effects becomes increasingly difficult the further away from the original scientific research the process moves, and the greater the importance of complementary investments and feedback loops necessary to obtain economic impact.

Adopting the conceptual framework suggested by the logic model captured in this schematic diagram highlights four key issues for analysing the impact of publicly funded research. The first is the critical importance of complementary investments. These may well be beyond public sector control and are almost invariably situated outside the confines of the university sector generating the research outputs; hence the importance of locating publicly funded research in its wider system setting before attempting any assessment of its impact.

The second relates to the long time-scales involved, especially when this is combined with often extreme uncertainty associated with the conversion of R&D (whether public, private or some combination of the two) into economic impact. This relates directly to the third key issue, which is recognising the 'skewness' of the returns to innovation, and hence to the impact of public funding of research. In any private and public sector research activity, a very high proportion of the total 'impact' generated will be accounted for by a handful of the most successful outcomes. There is widespread evidence for this skewness covering patents, initial public offerings, new drugs and venture capital investments. Between 50% and 80% of total value created will typically be accounted for by the 10-20% most successful members of the sample (see, for example, Scherer, 1999). The same is true for public policy interventions in this area (see, for example, PACEC, 2001, for the case of the UK Small Firm Merit Award for Technology, SMART). This means that the vast majority of publicly funded research efforts will not have significant final-stage commercial or financial impacts, and that a few mega-impacts will dominate average effects. This suggests that evaluations, for example of specific individual Research Council-funded programmes or projects, should be seen as part of an overall portfolio of UK Research Council funding. We should expect large numbers to proceed effectively through the various stages from activity to outcome but many to be honourable 'dead-ends' in terms of final impacts, with the bulk of the overall gains accounted for by a few final 'impact' successes.<sup>17</sup>

Finally, it is important to note that where (as in the case of some social and economic research) the impact is to be assessed with regard to policy development, the ultimate socio-economic impact

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<sup>17</sup> Equally if we regard all public sector funded research as part of a portfolio, we should expect to find only a small proportion of such programmes reporting outstanding success. If evaluators commissioned to carry out the research are inclined to report favourable results to the commissioning bodies, we might expect a more frequent occurrence of positive outcomes. On the other hand, most of the problems in assessing the impacts of publicly funded research lie in not being able to capture wider non-quantifiable benefits, with the result that evaluations will tend to be biased towards lower-bound estimates.

may be negligible or negative depending upon the 'success' of the policy itself. Equally, where, for example, wider cultural or quality-of-life impacts are at issue (as in the case of some arts and humanities research), impacts may be difficult to measure. Estimates of willingness to pay for the benefits can be made (e.g. based on actual payments for admission to exhibitions or estimates based on costs incurred in visiting linked to travel costs or work time given up) but the limited availability of such 'proxy' measures may mean that wider benefits are ignored and the overall impacts underestimated.

One stream of literature analysing the impact of public sector research on economic activity has essentially collapsed these complex logic model pathways into a knowledge production-function methodology. In this approach, the overall change in economic output or productivity, whether at the level of the economy, sector or firm, is accounted for in terms of changes in the inputs of labour, capital and knowledge. Knowledge may be decomposed into knowledge generated by the public sector and the private sector. (For a recent example, see Guellec and Van Pottelsbergher de la Potteries, 2004, and for earlier literature see the references cited in Salter and Martin, 2001.) This approach may be useful in identifying broad statistical relationships but it generally requires a host of simplifying assumptions about the precise underlying nature of the production technologies linking inputs to outputs, the weights to be attached to each 'factor' of production in estimating their impact on output and productivity, and the time-lags between the application of a particular input (e.g. publicly funded research) and its associated output. More importantly, by themselves such studies tell us very little about the causal processes through which the estimated impacts occur or the nature and scale of the complementary investment required.

An emphasis on process and complementary investments highlights the importance of understanding the multiple pathways through which knowledge can diffuse across organisational boundaries into commercial and economic applications, and invites a 'narrative' approach to impact assessment. This can support quantification of 'impacts' with qualitative assessment of non-quantifiable behaviour and the development of measures of different kinds of 'output' at each stage of the logic path. Applications of these insights can be associated with augmenting the Treasury logic model with a variety of 'output' measures at the various stages shown in Exhibit 7 (see, for example, the 'payback' approach originally developed for assessing health research impact by Hanney et al., 2004) or developing cost-benefit balance-sheet approaches in order to combine multiple types of outcomes and outputs associated with policy programmes (e.g. PACEC/CBR, 2009).

Finally, long time-scales, uncertainty and complementarities also make it helpful to assess changes in 'intermediate' level activities and outcomes rather than focussing solely on final output or impact

effects. This is especially so when evaluations are required based on political cycle timetables (i.e. five years or less) even though many final impacts may take ten or more years to appear. Intermediate changes include in particular behavioural changes affecting the development or use of the various pathways discussed above. These aspects are, as a result, increasingly emphasised in impact assessment, with the result that behavioural as well as output impacts have become a part of impact evaluation processes (Gök and Edler, 2010; Hughes et al., 2011b).

Thus, Donovan (2011), in an introduction to a special issue of articles reporting the results of a workshop that brought together leading contributors to field of assessment of research impact, notes that

“Metrics-only approaches employing economic data and science, technology and innovation indicators were found to be behind the times: best practice combines narratives with relevant qualitative and quantitative indicators to gauge broader social, environmental, cultural and economic public value” (ibid., p.175).

Insofar as we are concerned with examining the way in which the boundaries between university and industry sectors are made more permeable, this implies a close examination of pathways and the behavioural changes that occur at the boundaries of organisations across which individuals interact in the process of translating public research into economic impacts (see e.g. Hughes et al., 2011a).

In applying behavioural, payback and narrative methodologies, one can distinguish between ‘forward tracking’ narratives and impact assessment and ‘backward tracking’ narratives and assessment. The former take a particular programme of research or a research project and attempt to trace its impact via subsequent developments ‘using’ the research. The latter begin with an ‘impact’, such as a major medical breakthrough to commercialisation and treatment, and then try to trace backwards the key inputs into the events or breakthroughs contributing to the impact. All of these approaches may involve the use of interview-based case studies alongside primary and secondary data-gathering, which may involve surveys, bibliometric techniques or attempts to place a ‘value’ on outputs at each stage of the process from research to impact.

In our review of the empirical evidence, we include examples of each of these methods. Our presentation of the relevant evidence begins with a discussion of impact pathways, academic and business perceptions of their role, and constraints to the effective operation of the impact pathways. We then look at attempts to attribute quantitative values in terms of revenue flows or other market values associated with these pathways, and the economic impact associated with policies to support

them. We next review the limited econometric evidence relating to impacts on output and productivity growth at an aggregate level in the UK, and follow this with a review of a wide range of quantitative and qualitative assessments at the sector or disciplinary level. This includes assessments of a number of UK research council-funded projects, programmes and centres, using forward and backward tracking methods as well as payback methodologies, and extending over arts and social sciences as well as natural sciences.



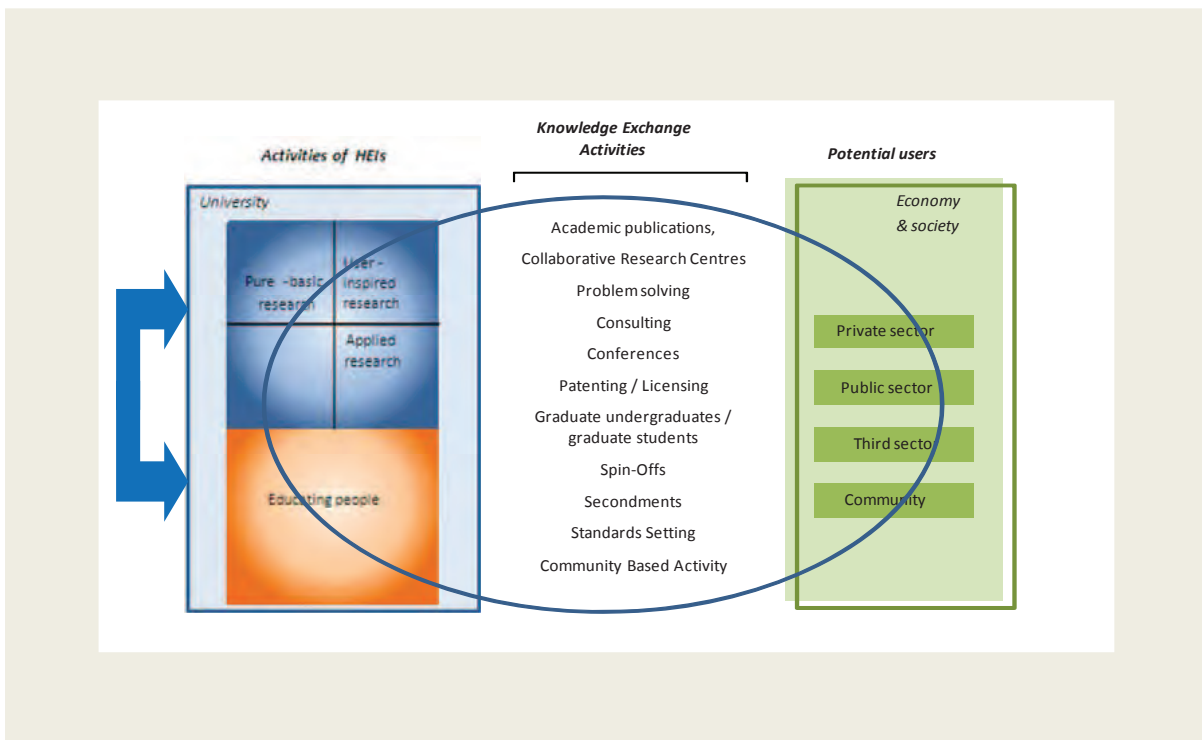


### 3. Impact Pathways

#### 3.1 Multiple Pathways to Impact

Exhibit 8 combines our earlier discussion of Pasteur’s Quadrant with that of the role of higher education and impact pathways to illustrate the multiple links by which the transition from activities to outputs may occur, and by which publicly funded research in the university sector may impact upon society as a whole through the private sector, the public sector, the third sector (of charities, NGOs etc.) and the community. The strength and effectiveness of these interlinking pathways will depend both upon the potential flow of new ideas from the science base and upon complementary investments by external organisations through which the exchange takes place (CIHE, 2010c). In the case of exchanges with potential economic impact, this generally requires business sector investment. In following sections, we set out the evidence in relation to each of these pathways.

**Exhibit 8 Knowledge Exchange and Pathways to Impact**



Source: Adapted from Hughes et al. (2010b).

### 3.2 Publications and Human Capital Mobility Pathways

One relatively visible aspect of the 'output' from university research is publication in the form of books and journal articles. A recent major survey provides an in-depth analysis of the UK's performance in both publication and citation terms. Perhaps of more relevance here, it looks at who accesses and cites such publications, and the interrelationship between business and academia as reflected in co-authorship and in the movement of researchers between the corporate and academic spheres (Elsevier, 2011).

The UK scores highly as a research publishing nation. Of the top five research nations based on academic article output in 2010 (US, China, UK, Japan, Germany), the UK has the most productive academic community. It generates more articles per researcher, more citations per researcher and more usage of the articles it produces (as measured by global downloads of UK articles). Moreover, the UK spends far less in absolute terms than either of these comparator countries. Indeed, the UK has become increasingly 'efficient' over time in terms of output per researcher and per unit of research funding. The UK output is also amongst the most highly ranked. The UK share of the world's top 1% of most highly cited papers was 13.8% in 2010, which placed the UK second only to the United States. When such citation indicators are weighted to adjust for the different citation practices in different subject fields and for different subject mixtures across comparator countries, the UK remains second only to the US and has been closing in on it in recent years. The UK has strong and improving research performance in clinical sciences, health and medical sciences, social sciences and business, and the humanities (Elsevier, 2011; *passim*).

Having high rates of transmission of codified knowledge through publication by academics and achieving high citation rates for those publications tells us relatively little, however, about business access and use of those publications. Nor does it provide information on the extent to which there is transmission of tacit knowledge through the inter-sector career mobility of those involved in the research.

It is possible to examine the extent to which non-university organisations download research articles. This provides an interesting indicator of cross-sector usage of university basic research and corporate-authored research publications. Here, the Elsevier (2011) analysis shows strong cross-sector knowledge flows. When an analysis is made of downloads of research articles by corporate users, it turns out that more than 40% were of university authored articles, with the rest made up equally of articles authored by hospitals, research institutes and firms. Likewise, more than 77% of all downloads of corporate-authored articles came from users in the academic sector. This suggests

a rich pattern of interaction and a strong indication of the role of publications as a pathway to potential impact in the UK.

Publications incorporate codified knowledge. Tacit knowledge embodied in people, in contrast, flows through people moving around and this, too, can be tracked through data on the authorship of publications. In the UK, more than 8,500 authors with a non-corporate affiliation moved to a corporate organisation in the period 1996-2010. The largest proportion of these (roughly two thirds) moved from a university. This is close to the rate experienced in most of the comparator countries considered in the Elsevier study. At the same time and over the same period, over 7,200 authors with a corporate affiliation moved to a non-corporate entity, which in two thirds of cases was a university. This again is similar to the pattern observed in the comparator countries considered in the Elsevier study, namely Germany, France, Italy, Japan, Canada, USA, Brazil, China, India and Russia.

Finally, it is important to emphasise human capital mobility in the form of graduate and postgraduate recruitment pathways and their role in the process of knowledge exchange. DTZ (2011), for example, assessed the impact of EPSRC support for PhD students using a survey of 86 companies and 20 follow-up cases in five research and innovation intensive industries in the UK – namely, chemicals and chemical products, basic pharmaceutical products and preparations, engineering-related consultancies, electronics and electrical equipment, and IT (computer programming, consultancy, interrelated services and information services activities). These industries are intensive PhD recruiters and account for the bulk of UK R&D. The analysis showed that the primary purpose in recruiting PhD students is to raise the overall performance capability of the organisation. Generic research competences of doctorate holders are rated most highly. In particular, the following four research skills were rated as very important by the percentages shown in brackets: problem-solving skills (75%), research skills and methodologies (63%), communication (59%), and data analysis abilities (56%). Direct impacts in terms of acquiring technical expertise, innovative and creative thinking, and problem-solving and troubleshooting were the most highly valued attributes of PhD recruits. Indirect impacts were also sought in the recruitment process in terms of team-working, networking, and absorptive capacity. This is linked to the increasing importance of collaborative working practices in R&D-intensive sectors. Finally, around three quarters of the respondents to the survey indicated that the contribution of doctorate holders to the commercial performance in their organisations was either high or medium, while 83% of respondents believed that the doctorate holders recruited had improved their competitive standing in the market and that their impacts developed very strongly during the first two years with the

organisation. Similar conclusions emerge from more widely based surveys of employers' attitudes to PhD recruitment (see e.g. CIHE, 2010a, p.5).

Other studies have focused on estimating the salary premium earned as a result of gaining doctoral qualifications. This is then used as a proxy measure of impact, since it reflects market valuations of the 'value added' by the degree. Thus, it has been estimated that EPSRC EngD programme graduates enjoyed enhanced career earnings of between £100-300K while PhDs graduating under sponsorship from the former Particle Physics and Astronomy Research Council (PPARC) gained £70K. In the case of the EngD, the grossed-up upper-bound estimate of the salary premium was £80million, representing a substantial benefit-to-cost ratio when compared to the scheme's cost of £12 million, whilst the PPARC benefit was rather less remarkable, being "comparable to the cost of their training even before consideration of broader research outputs" (PA Consulting and SQW Consulting, 2007, Part I, p.3, and Part II, pp.122-137 and pp.255-266, summarizing work carried out by EPSRC and DTZ Consulting).

Taken together these results reinforce the importance of human capital mobility in the knowledge exchange process and the significant contribution made by doctoral training programmes and PhD mobility for enhancing the absorptive capacity and competitive capability of R&D-intensive businesses.

### ***3.3 Commercialisation, Problem-solving and Community-Activity Pathways: Academic Perspectives***

Two recent surveys provide evidence of academic involvement in a variety of impact pathways. Salter et al. (2010) report on a survey of academics funded by research grants from the Engineering and Physical Sciences Research Council. The survey was undertaken in 2009 and covered the entire population of academics named on grants from the EPSRC since 1999. This included those with grants that did not involve a business collaborative partner. The survey followed up an earlier survey in 2004 and therefore allows comparisons with previous experience. The survey yielded 2,084 responses, with a response rate of 34% from the population surveyed, and included 756 individuals who responded in both 2004 and 2009. The survey results show that academics report a wide range of pathways to industrial engagement. The most frequently mentioned are conferences and one-off research agreements, including joint research projects and contract research. Most academics engaged in one or two types of impact pathway with industry in the two years prior to each survey. The survey comparisons between 2004 and 2009 also showed an increased level of engagement

with industry over that period. Academics perceived relatively few engagement problems arising from intellectual property or university rules and regulations. The main difficulties perceived related to research orientation including the time-scale and nature of the research. The academics reported that barriers to engagement appeared to be declining over time. In terms of the reasons for engaging with industry, the main factors that motivated academics related to a positive relationship with their research activities. In particular, positive responses were received in relation to securing additional research funding, and the identification and development of new and interesting research problems. Very few of the sampled academics engaged with industry for purely personal financial gain. The building of networks appeared to be increasing in importance as a factor. Otherwise the factors affecting engagement with industry remained fairly constant over time.

The respondents indicated a high level of involvement in developing new business ventures. The respondents to the survey were almost five times more likely to be involved in entrepreneurial efforts than general members of the UK population (as reflected in a comparison between survey respondents and respondents to the UK element of the Global Entrepreneurship Monitor (GEM) survey of entrepreneurial attitudes).

The second recent UK survey covered all academics across all institutions and disciplines in the UK (Hughes and Kitson, 2012). This survey was conducted between September 2008 and June 2009, so that the timing is broadly comparable with that of the survey of academics receiving EPSRC funding. The survey covers 22,129 respondents, representing an overall response rate of 17.6% from the total UK academic population. Of the 22,129 respondents, 3,623 were in health sciences, 7,590 in STEM subjects, 3,680 in the arts and humanities and 7,236 in the social sciences. This is broadly representative of the UK academic population. The survey respondents were somewhat more likely to be older and more senior members of the profession. This survey included questions asking academics about their commercialisation activities in terms of patenting, licensing output to a company, forming a spin-out company (taken together to constitute 'narrow' commercialisation) or forming or running a consultancy linked to their research (i.e. wider or 'soft' commercialisation). Exhibit 9 provides an overview of their responses.

## Exhibit 9 Commercialisation Activities by UK Academics 2005- 2008(%)

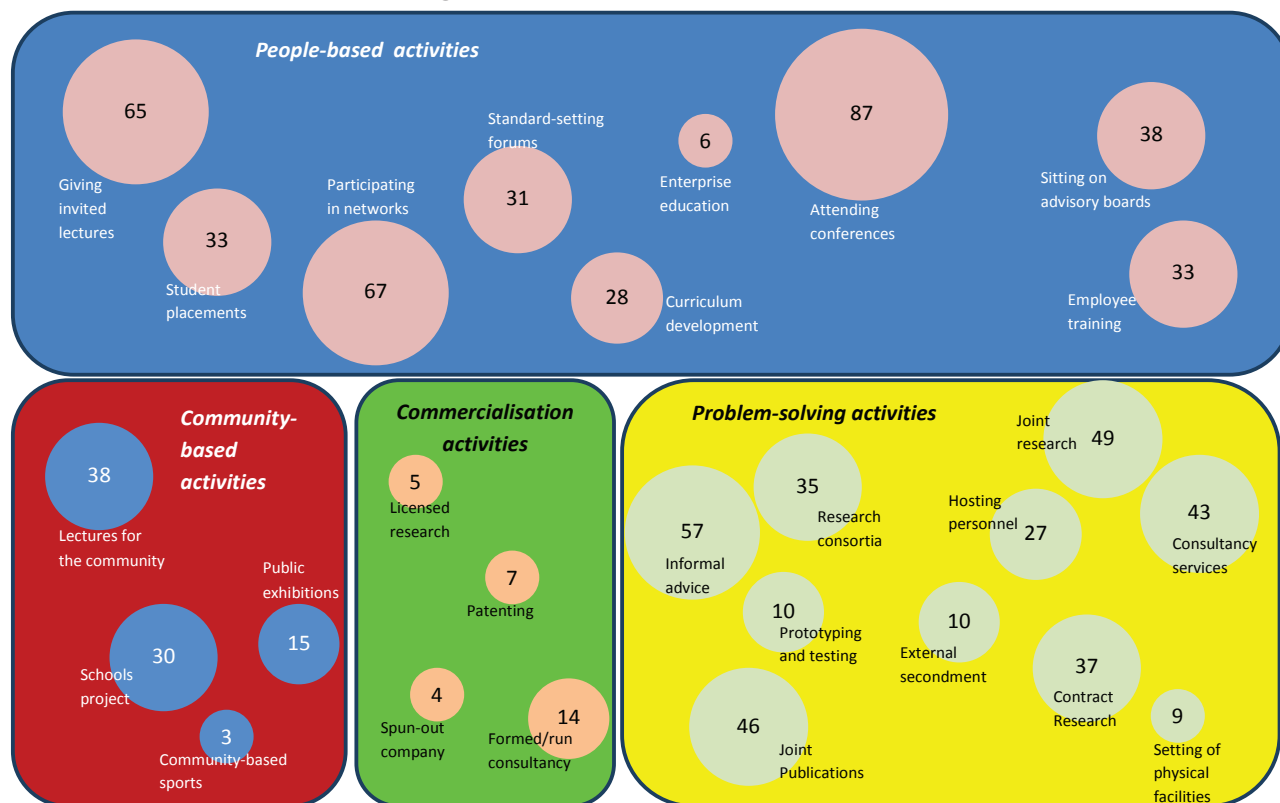
	Taken out a patent	Licensed research outputs to a company	Formed a spin-out company	'Narrow' commercialisation	Formed or ran a consultancy via your research	Total respondents
<b>All</b>	7.1	4.7	3.5	11.0	13.8	18,991
<b>Health sciences</b>	8.0	4.7	2.8	10.8	10.3	3,154
<b>STEM</b>	15.5	9.0	5.7	21.0	17.0	6,602
<b>Arts and humanities</b>	0.6	1.4	1.8	3.4	7.5	3,092
<b>Social sciences</b>	0.9	1.8	2.3	4.2	15.5	6,143
	**	**	**	**	**	

Note: \*\* Differences across subgroups statistically significant at 5% level or better.

Source: Hughes and Kitson (2012).

The exhibit shows that 11% of all academics have been involved in either patenting, licensing or forming a spin-out company, with the latter being the least common activity. Academics in the STEM subjects are most active in these 'narrower' commercialisation activities. Thus, 21% of such academics report a 'narrow' involvement in commercialisation over the previous three years. The exhibit is also important for showing that where a slightly 'softer' form of commercialisation through the formation or running of a consultancy is concerned, a much higher proportion of academics is involved. In particular, in the arts and humanities and the social sciences, the proportions reporting having formed or run a consultancy are respectively two and four times higher than those for academics involved in 'narrow' commercialisation. An important implication of this table is that it is likely that the role of disciplines outside STEM will be underestimated if we focus on impact pathway relationships linked to patenting, licensing or the formation of spin-out companies. The academic survey also included questions about a much wider range of impact pathways and included interactions with the public sector and the so-called 'third sector' of charitable, not-for-profit and community-based organisations. The results are shown in Exhibit 10.

**Exhibit 10 Impact Pathways of UK Academics (% of academics reporting each interaction with an external organisation)**



Source: Hughes and Kitson (2012).

This figure reveals that direct commercialisation pathways represent a small minority of all academic interactions with external organisations. The most frequent types of interaction with external organisations take the form of what are defined as ‘people-based’ activities in this survey. Thus, 87% of academics reported having attended conferences with external organisations in the previous three years, and 65% had given invited lectures. Equally, a very high proportion were involved in problem-solving activities, with 57% reporting informal advice in this connection, 49% reporting joint research, 43% involved in consultancy services and 37% in contract research. Joint publication is also substantial, which echoes the results obtained in the study of publication and research performance activities by Elsevier (2011) reported earlier. Finally, academics are involved in a wider range of community-based activities involving public exhibitions, schools projects, community-based sports and lectures for the community, all of which have a much wider socio-economic impact than is captured by commercial transactions alone.

## Exhibit 11 'High interaction intensity' by discipline (%)

	'Narrow' Commercialisation	Consultancy	Problem solving interaction	People based interaction	Community based interaction	All interactions	Total respondents
<b>Health sciences</b>	10.8	10.3	19.3	26.4	16.3	22.6	3,606
<b>STEM</b>	21.0	17.0	23.7	17.0	23.1	21.9	7,551
<b>A&amp;H</b>	3.4	7.5	8.1	17.3	34.5	14.0	3,655
<b>Social sciences</b>	4.2	15.5	18.8	19.4	24.3	20.1	7,204
<b>All (%)</b>	11.0	13.8	17.7	21.7	22.2	20.2	
<b>All (N)</b>	19,090	19,034	3,842	4,763	4,705	4,452	22,016
	**	**	**	**	**	**	

Note: \*\* Differences across subgroup statistically significant at 5% level or better

Source: Hughes and Kitson (2012)

The variation in the importance of these kinds of pathway activities by discipline is shown in Exhibit 11. This exhibit looks at the variation in 'high interaction intensity' across disciplines. ('High interaction intensity' is defined as being where an individual academic is involved in more than the mean number of activities under each of the headings shown in the previous exhibit.) An important variation in impact pathways between disciplines is apparent, with STEM subjects being least prominent in terms of people-based links and most prominent in 'narrow' commercialisation and problem-solving. However, high percentages of intensively interacting social and health scientists are also active in these pathways.

We can now turn to the motivations and constraints relating to interactions. As in the academic survey results reported by Salter et al. (2010), academics were primarily motivated by the opening up of new research networks and by potentially novel and interesting scientific research problems as well as by exposure to new developments in thinking in their fields. Very few reported the possibility of personal financial gain as being a factor, although scientists in particular were likely to mention the importance of attracting funding for their research or facilities.



### 3.4 *Impact Pathways: Business Perspectives*

As stressed earlier, businesses may draw on a wide variety of sources of knowledge for innovation beyond the science base. A number of recent surveys for the UK have cast an interesting light on the wider set of relationships involved. These help to set university links in perspective as well as enabling us to probe more deeply into the nature of the particular routes linking industry with universities and the constraints affecting such links (Cosh et al., 2006; Cosh and Hughes, 2010; Brunel et al., 2009). These studies have been accompanied by a growing collation of data arising from successive waves of the UK component of the European Harmonised Community Innovation Survey (CIS) (see, for example, BIS UK Innovation Survey, 2010).

Bruneel et al. (2009) surveyed 646 firms in 2008 that had collaborated on projects funded by collaborative research grants from the Engineering and Physical Sciences Research Council (EPSRC) between 1999 and 2008. This allowed a comparison with a similar survey conducted by the authors in 2004. The response covered around one fifth of all potential respondents, with approximately 70% accounted for by firms with fewer than 250 employees. The survey posed questions about the frequency of interactions by type of engagement pathway, the importance of different factors influencing the decision to interact with universities, the proportion of a firm's innovation activities that made use of outputs from universities, and the benefits and barriers associated with these interactions. The sectors covered by the respondents included chemicals and chemical-related industries, machinery and metals, electronics and instruments, transport, utilities and construction, business services, and a miscellaneous group. In both this and the earlier survey, a wide variety of forms of engagement emerged, in which attendance at conferences and the recruitment of graduates alongside joint research topped the list of interactions engaged in at least once over the prior two years to each survey. These forms of interaction were followed by student placements and contract research, training of company employees, consultancy, post-graduate training, and finally creation of physical facilities. Over two-thirds of businesses had been involved in joint research, recruitment of graduates and attendance at conferences with universities in the two years prior to the survey, and over half had been involved in student placements. Between 40% and 50% had been involved in contract research and the training of company employees, and over 40% with post-graduate training and with consultancy. These firms are, of course, a self-selected group in the sense that they were involved in collaborative research with universities, but the most significant point to emerge from this analysis is the very wide range of interactions.

In terms of the reason for interacting, access to state-of-the-art research was top of the list in both the 2004 and 2008 surveys, being ranked as 'very important' or 'crucial' in both surveys. This was

followed by access to problem-solving skills and access to R&D facilities. Access to research networks was ranked fourth in both years, with roughly 36% and 39% reporting this as a very important or crucial reason in 2004 and 2008 respectively. Outsourcing R&D activities was bottom of the list in both surveys, with around 22% in 2004 and 15% in 2008 reporting this as a very important or crucial reason for interaction. Around 30% had engaged in interactions to undertake exploratory research or to build up new research areas, and around a quarter to obtain feedback on the development process. This indicates that the engagement with universities spans the full spectrum of research and development activities and is not solely concerned with access to basic research alone, although that remains at the top of the list.

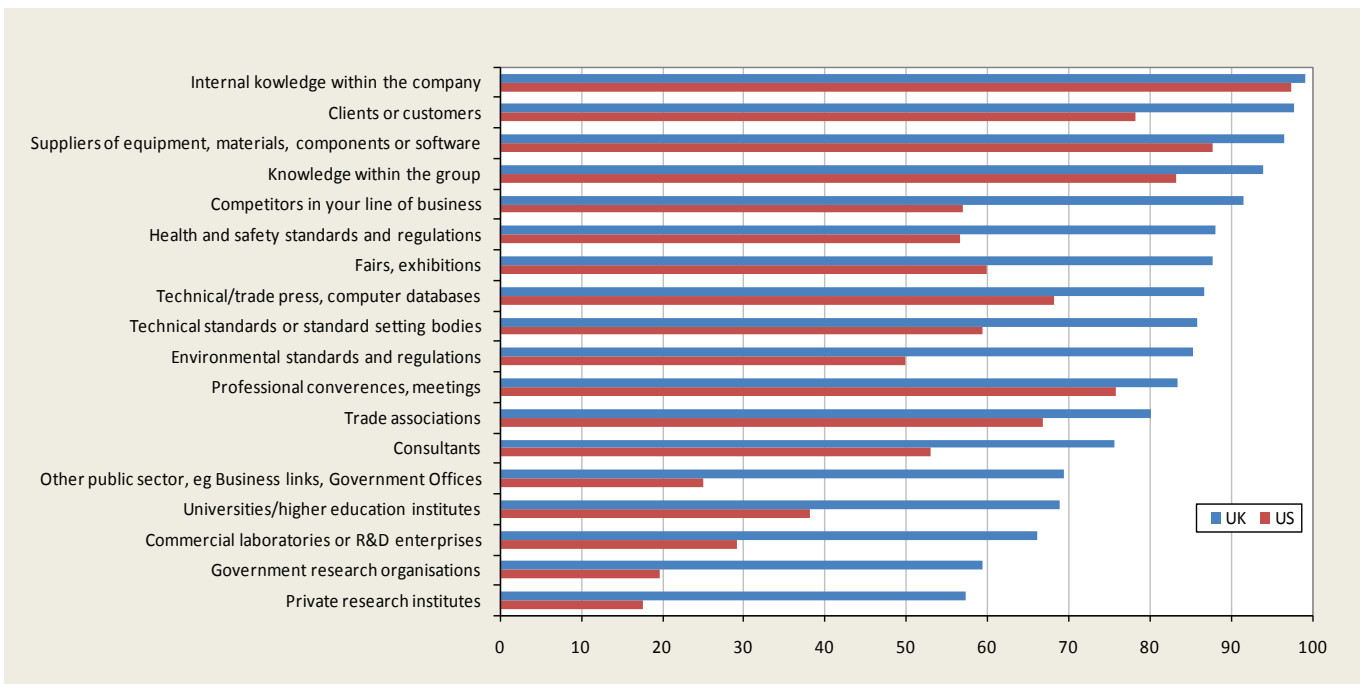
The firms were also asked to indicate which 'outputs' of universities they had used in relation to innovation projects. It is important to note that 'published results of research' was top of the list in both the 2004 and 2008 surveys. Over 50% of firms indicated that they relied on this output for at least 10% of the research involved in their innovation projects. The second and third most common outputs were hiring research graduates and general knowledge from basic research. The least frequent activity was support in the very late stages of innovation projects, followed by prototyping and design. Only a small proportion of firms indicated that they interacted with universities for the purpose of problem-solving when their development processes were moving closer to markets. A comparison of the 2004 and 2008 surveys showed some evidence of a decline in the general use of university outputs for innovation projects, although this may have been influenced by some slight changes to the questionnaire used between the two survey years. Finally, in relation to the perceived benefits of interacting with universities, the source most frequently cited as having been very important or crucial was the creation of long-term links.

With regard to barriers to interaction, the firms cited the relatively long-term orientation of university research and the lack of suitable government programmes in specific research areas. These were cited by around two-thirds of the sample as being either very important or crucial. Over 55% cited rules and regulations imposed by universities and governments as concerns in relation to confidentiality, intellectual property and the role of TTOs. Interestingly, a lack of mutual understanding and a strong orientation to basic research were seen as the least important factors posing a barrier to interaction. A comparison between 2004 and 2008 suggested that there had been an increase in the barriers experienced by firms working with universities. The greatest change related to the belief that university technology transfer offices (TTOs) had developed unrealistic expectations in relation to the value to be extracted from university-industry links, a change that may well be a consequence of government policies encouraging universities to exploit their

intellectual property more aggressively. The number of firms citing this barrier as very important or crucial doubled from 24% to 49% over the period 2004 to 2008. Both the barriers and the changes over time seem to be of equal significance for large and small firms in the sample. The authors speculate as to reasons behind the perceived increase in barriers to interaction, placing particular emphasis on the perceived increase in the role of professionalised TTO offices with often rather unrealistic expectations of the economic value of research. They also note that the survey in 2008 coincided with the period leading up to the Research Assessment Exercise (RAE) of that year, with a likely consequence being a focus by academics on their publication record rather than their university-industry interactions as they approached the RAE submission date. Finally, we note that the development of clearer, stricter rules and regulations governing research conduct and technology-transfer relationships may have led to more frequent and complex negotiations in launching collaborative research projects involving, in addition to university researchers and the company, the university research administration and the technology transfer office.

Cosh et al. (2006) and Cosh and Hughes (2010) analysed a survey of over 3,500 UK and US businesses in the manufacturing and business services sectors in the period 2004/5. The sample included 1,540 US businesses and 2,129 UK businesses. The sample covers the full size range of businesses from 10 employees upwards. Approximately two thirds of the sample employ more than 10 but fewer than 100 staff, approximately 20% employ between 100 and 999, and around 13% employ 1,000 or over. This survey is unique in allowing a direct comparison between the UK and the US. The businesses surveyed were asked about the extent to which they used universities as one amongst a number of potential sources of knowledge for innovation, and the value they placed upon them. They were also asked in detail about the extent and form of interaction with universities *per se*. The sources of knowledge and university-industry link pathways analysed in the survey draw on the work of Salter et al. (2001) and Cohen et al. (2002) as well as previous work by the authors themselves in piloting the design of the UK component of the CIS survey. The results of this UK-US survey show, in keeping with earlier studies for the US, that when businesses are asked about their sources of knowledge for innovation, universities and higher education institutes are some way down the list.

## Exhibit 12 Frequency of Use by Sources of Knowledge UK and US



Source: Cosh and Hughes (2010).

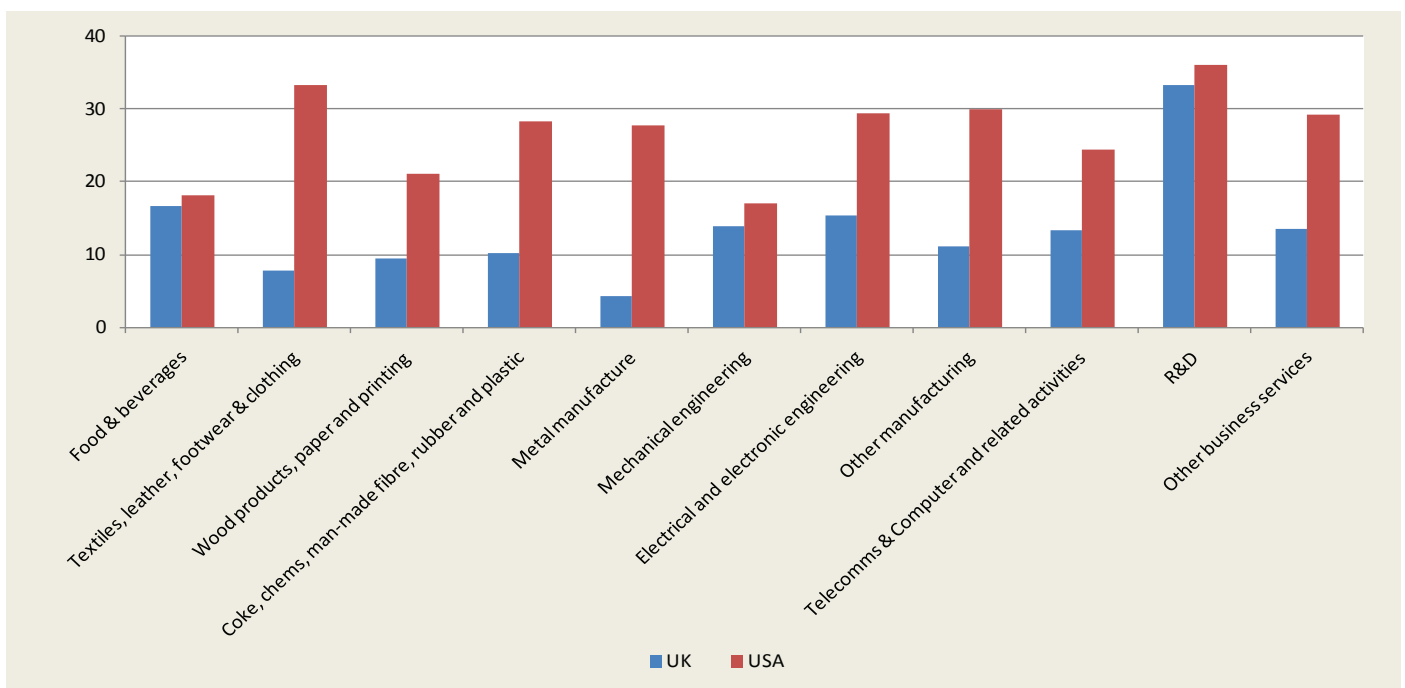
Exhibit 12 shows that the business sector itself is the most frequently cited source of knowledge for innovation. The company's own internal knowledge and knowledge drawn from clients or customers, or suppliers of equipment, materials, components and software, or competitors in the same line of business appear to be the most frequently cited sources in both countries. These are followed by a range of intermediating organisational structures and mechanisms. These include technical standard-setting bodies as well as professional conferences and meetings, trade associations, fairs, exhibitions, and consultancies. In both countries, universities and higher education institutes are ranked at the bottom of the list.<sup>18</sup> This general finding is important in illustrating the point that, in estimating the impact of universities, it is essential to consider them as part of a wider innovation system and not to over-emphasise the role that they may play independently in the innovation- and productivity-enhancing process. This point is reinforced when the survey data are analysed to consider the combinations of sources of knowledge drawn from three broad groups (business, intermediate and science base). When this is done (Hughes, 2007), it emerges that, although the business sector itself is the most frequently used source of knowledge, it

<sup>18</sup> It is sometimes argued that results of innovation surveys under-estimate the role of universities because the samples include conventional or low-tech businesses and many smaller businesses which may not be involved in university-related activities because of the nature of their business or their lack of innovativeness. However, Cosh and Hughes (2010) compare samples of *innovating* UK and US firms, matched in terms of size and sector, and the same picture emerges in terms of frequency of use of universities as a source of knowledge and in terms of patterns in the combinations of knowledge sources used.

is hardly ever used in isolation. In the case of the UK, only 1% of the businesses report using the business sector alone while 18% report using the business sector together with intermediaries. In the US, the corresponding proportions are 2.8% and 42.5%. The US therefore appears to exhibit a richer pattern of engagement combining the business sector with intermediary institutions to provide potential links to the science base and other knowledge sources. In the UK over 80% of the firms report using some combination of sources from all three groupings, whereas this is true in only 50% of the US cases. Hughes (2007) conjectures that this reflects a much more diffuse and less well integrated pattern of interactions in the UK compared to the US. This is supported by the evidence in Cosh et al. (2006) and Cosh and Hughes (2010), which reveals that, when firms are asked about the extent to which they commit resources in support of their university-industry links, US businesses are more likely to have invested in innovation-related expenditure on university activities.

As Exhibit 13 shows, US businesses also value the links more highly (Cosh and Hughes, 2010) and this result holds across a wide range of business sectors. It is important to note also that Exhibit 14 demonstrates that in both countries the importance attached to the role of universities varies by sector. This highlights the importance of understanding university links at a disaggregated level.

**Exhibit 13 Users of Universities as a Source of Knowledge rating them as highly important by Industrial Sector (innovators only)**



Source: Cosh and Hughes (2010).

It has been shown using CIS data that the benefits to innovation at the firm level from increasing the number of external collaborations follows an inverted U-shape pattern – in other words, innovation performance at first rises with the number of external collaborations, but then declines (Laursen and Salter, 2006). To the extent that UK firms report more multiple combinations but are less likely to invest in support of them, the problem for the UK may not be making too few connections but *too many*. Too wide a range of collaborations and a lack of the necessary investment to manage and exploit them effectively could lead to the links being weak and less valued. The UK pattern may also reflect a lack of appropriate intermediary or boundary-spanning institutions operating at the university-industry boundary (Mina et al., 2009; Hauser, 2010).<sup>19</sup>

The UK-US survey in addition asked the responding firms to indicate the types of university-industry interactions contributing to their innovation activities. In both countries, informal contacts were the most important contribution, followed by recruitment at first degree or Masters level, publications and conferences. This is consistent with the results for the UK emerging from the study by Bruneel et al. (2009). Some differences between the countries do emerge, especially in terms of the relatively more intensive use of, and value placed upon, internships in the US compared to the UK. It is important to note that patenting and licensing appear low down the list of business perceptions with regard to university interactions contributing to innovation. The UK-US survey also probed specifically into mechanisms for the acquisition of new technology involving universities rather than innovation-related activities more generally. Once again, in both countries publications and informal contacts were top of the list, whilst licensing was low down in terms of frequency and the value placed upon it.

In a third recent survey of UK businesses covering all sectors of the economy, Hughes and Kitson (2012) confirmed the findings on the relative scale and scope of interactions reported for manufacturing and business services and the sectors collaborating with EPSRC schemes. The survey also asked how interactions were initiated, with the results revealing that they were overwhelmingly the consequence of informal interpersonal interactions rather than through formal intermediaries such as Technology Transfer Offices. This survey also asked respondents to indicate which business functions they sought interactions to support. Taking all interacting firms together, the responses indicated that the primary motivation for interactions was for support in relation to marketing, sales and support services (cited by 49% of interacting firms), innovation activities (cited by 43%) and human resource management (cited by 38%), while logistics, procurement and operations were cited by 24% of firms that reported interactions with universities. This pattern does, however, vary

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<sup>19</sup> For a discussion of the critical role of intermediating engineering research consultancies in the development of the Cambridge science-based industrial complex, see Connell and Probert (2010).

significantly by discipline. Hence, for those businesses interacting with social sciences only, support for marketing and sales and human resources management was sought 50% of the time, and for innovation activities in 17% of the cases. Of those reporting STEM interactions, 64% did so in relation to innovation activities, 36% in relation to marketing, sales and support, and 19% in relation to human resource management. It is important to note, however, that a significant proportion of businesses reported interactions both with STEM and with social sciences. When this group is considered together, then marketing, sales and support services was reported by 59% of businesses, innovation activities by 47% and human resource management by 35%, with logistics at 26%. In addition to showing the importance of cross-disciplinary involvement by businesses and their interactions with universities, this also highlights the importance of assessing the impact that universities may have on business processes and decision-making as a whole and not just on the technical aspects of their innovation activities (Hughes and Kitson, 2012).

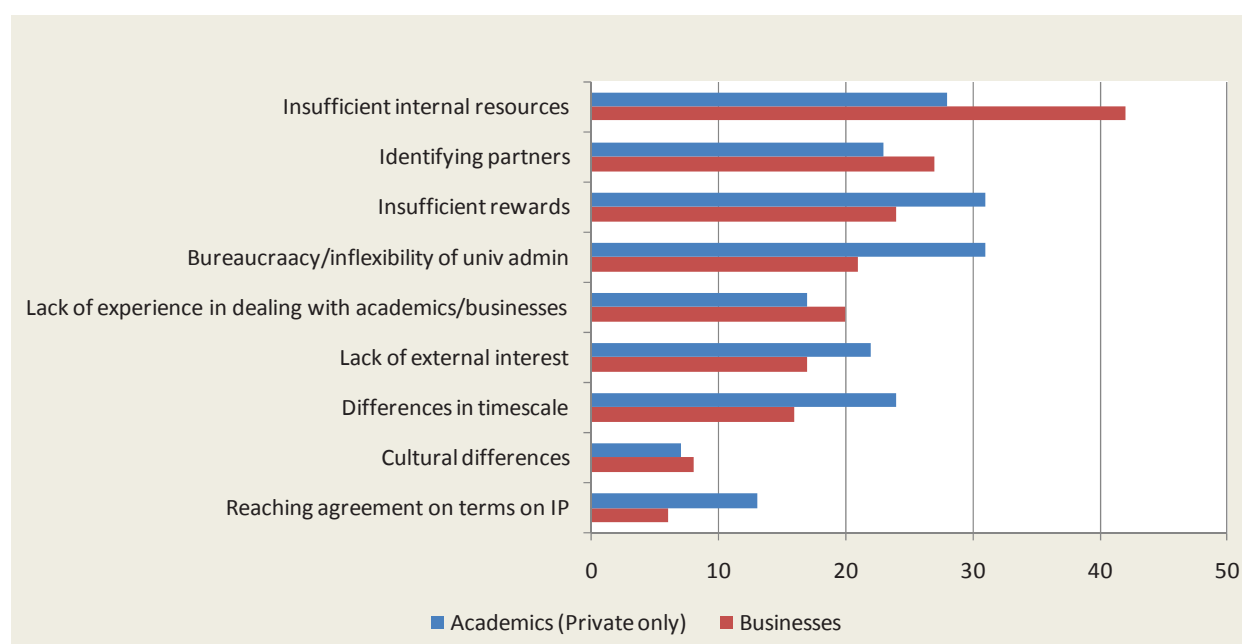
Taken together, these three business surveys indicate a rich pattern of engagement in the UK, in which technology licensing and spin-offs represent a relatively small part of the interaction pathways between the science base and the business sector. The results also confirm the central importance of publications, informal contacts and student recruitment as sources of knowledge for innovation and as ways of acquiring information and knowledge about new technologies. In addition, the results indicate the important role of intermediaries and of interactions through conferences and other networking events. A comparison of the results of the 2004 and 2008 surveys based on the EPSRC-collaborating business sample nonetheless suggests some issues for the UK. An overemphasis on technology transfer offices and the formalisation of relationships associated with them may have led over that period to a growing perception by business that this was an increasingly important barrier to interaction (even though, as we have seen, licensing *per se* plays a relatively small and specialised part in the overall scheme of interactions). In the case of the comparison of the UK and the US, it may be of concern that the evidence suggests that the UK has a diffused and relatively weak set of interactions. In contrast, a more focused use of intermediaries appears to be a feature of the US knowledge source pattern. Moreover, where university-industry interactions exist, the US firms both value them more highly than their UK counterparts and invest more themselves in their support and development. This reinforces the importance of business expenditure not only on research and development *per se*, but also on the development of network interactions with the university sector. These play a key part in influencing the impact that university research may have within a system of innovation at the national level.

### 3.5 Constraints on Impact Pathways: Business and Academic Perspectives

Finally, it is instructive to compare the patterns of constraints reported by businesses and academics who had engaged with the private sector only in this sample. In the parallel study of academics and businesses in the EPSRC surveys, the main difficulties perceived by both groups related to differences in research orientation including time-scale and the nature of the research. Business respondents were more likely to report barriers arising from intellectual property or university rules and regulations. Businesses reported concern that these barriers had increased between 2004 and 2008, whilst the academics reported that barriers to engagement appeared to be declining over time. Whether these differences reflect a difference in experience between the sample respondents or a difference in perceived constraints and barriers relative to actual barriers is a moot point.

The constraints reported in the surveys covering all businesses and all academics are shown in Exhibit 14.

**Exhibit 14 Constraints on Interactions: Businesses and Academics engaged with Private Sector only (% of respondents)**



Source: Hughes and Kitson (2012).

First, the most frequently cited constraints that emerge on both the business and academic side are their own internal capabilities and capacities. Academics are evidently concerned about having



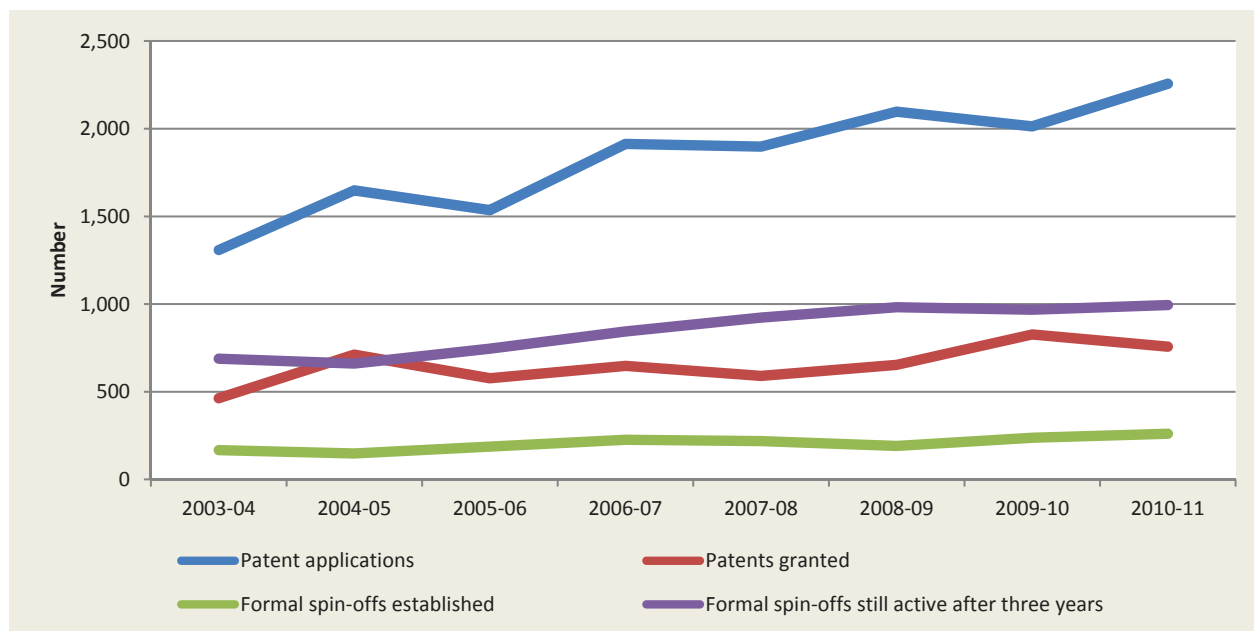
insufficient time and resources to support their activity and businesses, and most frequently cite insufficient internal resources to support the activity. Taken in combination with the earlier results on the relative lack of investment in university-industry links in the UK compared to those in the United States, this suggests that a major problem lies in the management of demand-pull characteristics in further developing university-industry pathways to impact. At the same time, there is a consistency in response between the overall academic population covered in this survey and the survey of academics involved in EPSRC research. Both emphasise a lack of time needed to combine pathway interactions with external organisations alongside internal teaching and research activities. This is also reflected in the high importance attached to inadequate rewards in the academic survey. Thus, over 30% of academics cited inadequate rewards as a barrier to interaction, roughly the same proportion as cited bureaucracy or inflexibility on the part of university administrators. This is closely linked to the perception (and probably the reality) that career progression is linked primarily to research publications rather than pathway engagement (Abreu et al., 2009). Problems stemming from differences in time-scale are relatively unimportant for the UK academic population as a whole. It is interesting to note that academics feel this more keenly than do businesses. Reaching agreement on the terms of IP, along with wider cultural differences, appears at the bottom of the scale. The relatively low rating for reaching agreement on the terms for IP reflects as much as anything the relative unimportance of IP-related pathways for the majority of university-industry interactions.

### ***3.6 Impact Pathways and 'Third Stream' Income Generation***

The concern with impact and accountability has led to the generation of various pathway-related indicators in the UK. The now annual Higher Education – Business and Community Interaction Survey (HE-BCIS) provides a number of impact-related metrics. The statistics need to be interpreted with caution since the increased requirements to report impacts and the incentives to intensify efforts to record and report relevant data may have led to an element of 'inflation' over time. The metrics include activity measures (indicating the number of spin-offs or patents generated) as well and income measures based on external revenue sources for collaborative research, consulting, teaching and intellectual property. Revenue incomes represent an indication of the willingness to pay for research and teaching services and to contribute to the funding of collaborative research. The income metrics are therefore proxy indicators of the impact generated by the various pathway activities funded. They can be combined with the results of other recent studies on spin-out activity and licensing by the Russell Group (2010) and Library House (2007), and by the individual Research

Councils as part of their annual impact reports (AHRC, 2011; BBSRC, 2011; ESRC, 2011; EPSRC, 2011b, MRC, 2011; NERC, 2011; STFC, 2011; RCUK, 2011).

### Exhibit 15 University Spin-off and Patenting Activity 2004-2011



Source: HE-BCI Survey 2010/11.

Exhibit 15 based on HE-BCIS data shows numbers of patent applications, patents granted, spin-offs, and spin-offs still active after three years. Patent applications rose from 1308 per year in 2003/4 to 2256 by 2010/11, whilst the number of patents granted increased from 463 to 757. Spin-offs grew from 167 per annum in 2003/4 to 260 per annum in 2010/11. Spin-off survival is perhaps a better indicator, since it is a proxy for quality. It is interesting, therefore, to note that the number of spin-offs surviving after three years (which includes spin-outs launched from earlier years than those shown in the chart) also rose from 688 to 994.

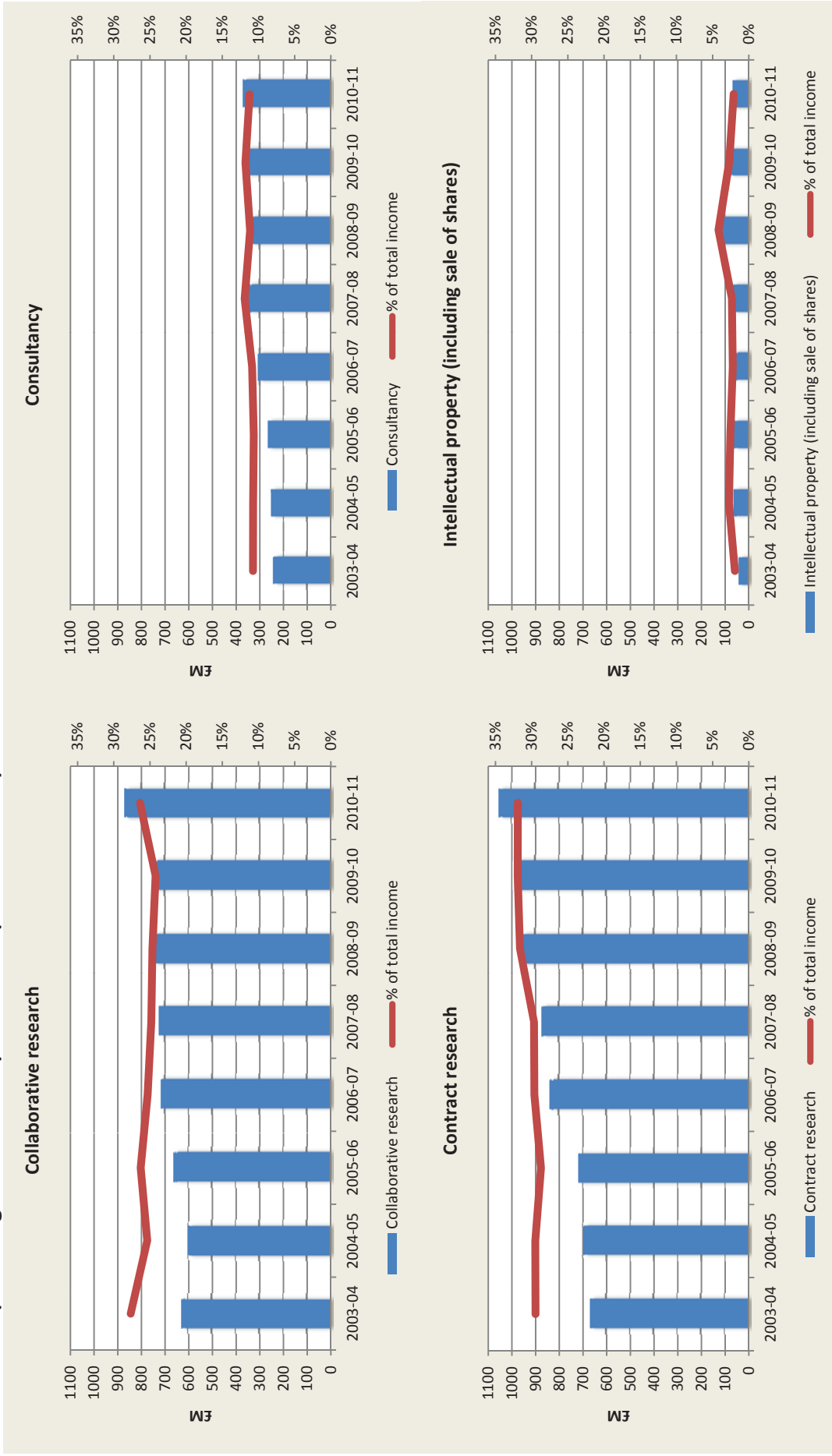
It is important to gain some idea of the scale of these activities in terms of revenue flows or market values. The Russell Group of UK research-intensive universities have attempted to arrive at an estimate using data collected from 125 impact case-studies identified in a 2008 survey of their members (Russell Group, 2010). They estimated that in the 66 cases where data were available, licensing revenues of just over £1billion had been generated over the previous 10 years. In the same period 24 companies had spun off with a combined estimated market value of £498 million, and a further 24 had secured commercial investment of £330 million. These impacts were highly skewed,

with 80% of the combined returns across the case studies accounted for by 20% of the cases. Indeed the top 2 cases (representing 3% of the sample) appear to have accounted for over £700 million or around 37% of the overall total of £1.9 billion (Russell Group, 2010, pp. 24-25, and Figure 3, p.25).

Using standard OECD definitions of basic and applied research, the Russell Group study also classified the cases in terms of basic and applied research. They identified 57% as having their origins in basic research and 43% in applied research. The most successful impact case (ranked in terms of licence revenues or spin-out valuation/funding) had its origins in basic research, whilst the second most important was derived from an applied research project. Of the next eight most successful impact cases, no less than seven were derived from basic research. Cases arising from basic research accounted for 74% of all licensing revenues, market valuations and investment generation (Russell Group, 2010, pp. 30-31, and Figure 5, p31).

There are very few international comparisons to indicate whether this performance is relatively good or not. Those that do exist are comparatively positive with regard to spin-offs. Thus, the UK university sector's ability to attract external revenues and to generate value through spin-outs appears to be good by comparison with the USA. In a comparison with Stanford, Washington and Wisconsin universities, only Stanford persistently ranked ahead of leading UK research universities in terms of investment generated per spin-out (Library House, 2007). Equally, the UK HE-BCIS data suggest that the research resource required per spin-off was £23million in UK compared to £56million in the USA. In the case of IP, however, the position is reversed, with IP income as a percentage of total research spending standing at 1.3% in UK compared to 3.7% in USA (HEFCE, 2011b, Table A, p. 30).

**Exhibit 16a Impact: External Income Generation from Collaborative research, Consultancy, Contract research and Intellectual property**  
 (including sale of shares) 2003-2011 (£m real terms)



Source: Derived from HE-BCI Survey 2010/11

**Exhibit 16b Impact: External Income Generation from Facilities and equipment-related services, Regeneration and development programmes and Continuing Education**



Source: Derived from HE-BCI Survey 2010/11

The HE-BCIS data also permit a wider review of evidence relating to revenue associated with impact pathways. Real income from external pathway sources more than tripled between 2001 and 2010 (PACEC/CBR, 2009; HEFCE, 2011b). Disaggregated data are shown for the period 2003 to 2011 in Exhibit 16. The largest component of pathway-related external income in 2011 was contract research, which generated £1054 million. This has increased in real terms in each year in the period covered and accounted for a share of total external pathway income which rose from 29% to 32% between 2003/4 and 2010/11. The next most important component in 2011 was collaborative research at £872 million which, although rising in real terms since 2004-5, has fallen slightly as a share of total income generated over the period. Continuing Professional Development and Continuing Education is the next most important source of pathway income and also shows an increase in real terms to reach £606 million, with its share rising from 15% to 18%. Regeneration and Development programmes, which are closely linked to regional and location-specific impact pathways, have been declining in recent years in real terms to £203 million, their share falling from 11% to 6%. This pathway income has been affected by the reorganisation of regional support policy in the UK and by the downward trend in EU and UK support for regional development. Use of facilities and equipment has remained at around 4% of income and accounted for £129 million in 2010/11. Intellectual property was the least important source of income in all years except 2008-9 and accounted for between 2% and 4% of income. Taken as a whole, these data suggest that external users of university pathways have exhibited an increased willingness to pay for access to university services, inputs and facilities, and hence imply a substantial increase in impact from these pathways.

## 4. Impact Effects of Public Policy Support for Knowledge-Exchange Pathways

### 4.1 *Knowledge Transfer Partnerships*

One of the most important pathways to impact is through the movement of people. This has been recognised in long-running support in the UK for a programme funding the exchange of graduate students between universities and firms as part of what was originally known as the Teaching Company Scheme (TCS) and now is called the Knowledge Transfer Partnership (KTP) scheme. The basic idea behind this is that a graduate (known as an associate) works for a firm usually for a two-year period on a specific knowledge-transfer project central to a firm's development. The technology that is subject to the knowledge transfer originates within a qualifying knowledge base partner, typically a university. The associates are jointly supervised by staff in the company and faculty at the university concerned. The programme originated in 1975 and has been subject to two substantial evaluations (Segal Quince Wicksteed, 2002; Regeneris Consulting, 2010). The KTP programme is distinguished by the fact that it emphasises the need for university-business partnerships to be led by business need. It is therefore an important vehicle by which knowledge exchange can occur through the transfer of individuals into a business environment from the university base, helping to embed a greater capacity for the business organisations involved to innovate in the future. (Regeneris Consulting, 2010). In 2008-9 around £30 million was spent in support of this scheme. Approximately two-thirds was funded by the Technology Strategy Board, with the remainder composed of funding from the research councils, regional development agencies and the devolved administrations, and central government departments. In addition to the public support for this scheme, in 2008-9 the businesses involved contributed a further £63.6 million. To the extent that business contributions represented an indication of willingness to pay and reveal a preference for this kind of activity, it is clear that the businesses expect useful impacts to arise from their involvement, and indeed this is reflected in the long-running nature of the scheme. Most of the business contribution is concerned with capital payments to support the exchange programme (Regeneris Consulting, 2010, p.13). Over 5,000 partnerships have been supported under this scheme since its inception, with a substantial increase in numbers since the 1990s. By 2008-9 there were just under 1,000 active partnerships compared to 654 active partnerships ten years previously. In 2009, 96 higher education institutions or universities started new knowledge transfer partnerships. However, a relatively small number of institutions dominate the overall number of partnerships, with almost half of the current partnerships being accounted for by academics from 20 knowledge-based institutions. In terms of the businesses participating in this scheme, it is important to note that around 90% of partnerships involve businesses employing fewer than 250 employees. This is,

therefore, an important vehicle in terms of exploiting potential public sector research impacts within the small business sector.

Our principal concern here is with the impact that involvement in this knowledge exchange has had on business performance and with the objectives of businesses taking part in the scheme. This provides a useful indication of the impact of public sector research activity supported by a complementary set of investments by the public and private sectors in the specific context of the scheme. The major review in 2002 (Segal Quince Wicksteed, 2002) revealed that university and higher education institution partners were drawn from across the full range of research intensity (where RAE ratings were used to classify the partners by research intensity). In the evaluation of this scheme, two types of impacts were identified: meeting commercial objectives and meeting technical objectives. Around two-thirds of the companies involved believed that the technical objectives of the programme were fully or almost fully met. Around 40% stated this had also been achieved in relation to meeting commercial objectives. Since market uncertainty is an additional factor affecting potential outcomes, it is only to be expected that commercial objectives might be less likely to be fulfilled than the technical objectives. Smaller companies and micro-businesses in particular were likely to be less successful than larger businesses participating in the scheme. In terms of 'bottom line' increases in sales, employment or profitability, less than half experienced possible gains. There was a wide range of benefits of these 'bottom line' types across firms, but of the total value of turnover generated a small proportion of firms accounted for the vast majority of the gains stemming from the programme as whole. This skewness in outcomes is typical of knowledge exchange activities in general, in keeping with the underlying nature of the innovation and business growth process (Hughes et al., 2002). There were substantial 'softer' benefits accruing to businesses as a result of enhanced skills and knowledge. These are clearly linked to embedding capacity in the partnering firms. Perhaps one of the most convincing indicators of the positive impact of university knowledge transmitted by this route was that 62% of the company partners subsequently offered the associate a permanent post and 84% of those individuals offered such a post accepted it.

A further review of the KTP programme took place in 2010 (Regeneris Consulting, 2010) and reached essentially similar positive conclusions in relation to impacts. This evaluation confirmed a wide range of knowledge exchange activities spanning management; marketing, business administration and policy; engineering technology; and IT, computer science and computation. These between them accounted for more than half of the active partnerships at the time of the evaluation. The proportion of micro-businesses involved had declined between 2004 and 2009, suggesting that the relatively weak impacts reported in the first evaluation were reflected in a decrease in involvement



of that kind of business in the scheme. In terms of 'bottom line' outcomes, this more recent evaluation suggested that between 5,550 and 6,010 net additional jobs had been created by the partnerships supported between 2001-2 and 2007-8. They also created between £4.2 billion and £4.6 billion of new sales for company partners and £1.6-1.7 billion and in terms of gross value added. Return on investment overall in the scheme was positive, estimated at somewhere between £4.70 and £5.20 net additional gross value added per £1 invested by the sponsors. The impacts were likely to be greatest in medium-sized companies in the sample. As in the 2002 evaluation, a substantial skewness in outcomes was revealed with the top 25% of businesses ranked by net gross value added impact accounting for more than 70% of the total net additional impact in the sample of firms analysed. In terms of jobs created the top 25% accounted for 60% of the total.

The overall operation of the Knowledge Transfer Partnership scheme reinforces the view that an important pathway to impact is through the movement of people, with the evidence suggesting that the contribution of UK higher education institutions through this particular route is significant.

## **4.2 Collaborative Research and Development Programmes**

Collaborative research and development projects are one of the major programmes by which the Technology Strategy Board<sup>20</sup> endeavours to raise levels of innovative activity. Since 2004 the objectives of the programme have been to encourage greater collaboration between businesses and academia, and to support projects that are likely to result in additional innovation or improved innovative capability, and which have exploitation potential as reflected in the business case for the collaboration (PACEC, 2011). These projects are focused on a range of enabling technologies (bioscience; electronics, photonics and electrical systems; high-value manufacturing; information and communications technology; and advanced materials in micro technologies). Another group have focused on what one might term 'market-led' projects, where the sectors involved are creative industries; environmental sustainability; energy generations and supplies; medicines and healthcare; and transport (subdivided into aerospace, low-carbon vehicles, and intelligent transport systems).

The 2010-11 evaluation (PACEC, 2011) focused on 336 programme participants who had been supported by the programme between 2004 and 2009. These participants were involved in 167 separate projects. Their experience in terms of outcomes was compared with that of a control group of 205 bidders who had not succeeded in obtaining support. In terms of impact, a number of metrics

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<sup>20</sup> The Technology Strategy Board is the UK's national innovation agency. It was established by the Government in 2007 and is sponsored by the Department for Business, Innovation and Skills (BIS).

were identified in this report. The first focuses on employment in terms of the number of actual and likely full-time-equivalent jobs created that would not otherwise have been generated. Gross value added in net additional terms (i.e. above what would otherwise have occurred) constitutes a second indicator. There were also various metrics relating to changes in attitude and behaviour with regard to a wide range of commercial and technical issues which were to be addressed in the projects.

Behavioural and attitudinal impacts related in particular to sharing investment risks, improved collaborative ability, the provision of access to technical advice and R&D skills, access to leading-edge research, improved innovation in R&D skills and processes, improved technical knowledge and understanding, the application of technologies to be explored in the project, and the assessment of the technical feasibility of ideas in the development of products and processes. These were each cited as objectives by between 57% and 90% of the partners interviewed in the course of the evaluation.

Accessing academic inputs through this scheme is associated with substantial 'bottom line' gains in terms of employment and value-added impacts. The evaluation estimated that the collaborative research and development programme since 2004 was likely to have generated a total of 13,350 net additional full-time-equivalent jobs, of which 8,900 arose directly from the programme, with a further 4,450 arising from wider supply chain jobs and linkages. It also estimated that the programme is likely to generate net additional gross value added of £2.9 billion. For each £1 of grant, the equivalent increase in gross value added is £6.71. Of particular relevance to this review is that the benefit of academic involvement was clearly demonstrated by the fact that the overall business impact in projects with two or more academic partners (£9.67 of gross value added) was more than double that in projects with no academics involved (£4.22) (PACEC, 2011).

### **4.3 Third-Stream Funding**

Between 2001 and 2010/11 HEFCE/OSI funding for knowledge exchange was channelled through successive rounds of the Higher Education Innovation Fund to promote a wide range of knowledge exchange and impact pathways. Around £1 billion was committed to support UK university knowledge exchange.<sup>21</sup> In 2008 an evaluation of this scheme was carried out. The evaluation used an innovation systems approach but was also set within a Treasury logic chart evaluation framework. This analysed the relevant inputs, activities, outputs and the resulting impacts, and it included an

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<sup>21</sup> For a discussion of the evolution of the scheme and the range of specific schemes supported, see PACEC/CBR (2009, pp.22-24).

analysis of behavioural as well as final economic impacts. In addition, cost-benefit balance sheets were produced which compared the inputs to the various outputs of knowledge exchange, and an assessment of behavioural additionality was also included (PACEC/CBR (2009), Hughes et al. (2011b)). A primary database was assembled from case studies of 30 HEIs; from the results of a survey of 1,157 academics and of 373 external organisations engaged in third-stream activities with HEIs; and from interviews with various stakeholders, including central government departments and the Regional Development Agencies (RDAs). The case studies were selected on the basis of a cluster analysis, in which six key clusters were identified, largely reflecting the scale of HEI's research activity (the top six HEIs, high research HEIs, medium research HEIs, low research HEIs, arts HEIs, plus all HEIs) (PACEC/CBR, 2009).

The study concluded that between 28% and 41% of knowledge exchange income could be attributed to HEFCE third-stream funding, and that the injection of £592 million by HEFCE in the course of its HEIF third-stream funding programmes between 2001 and 2007 generated between £2.9 billion and £4.2 billion in gross additional knowledge exchange income over that period. The lower estimate equates to a gross additional impact factor of 4.9. In addition, a large range of non-quantifiable impacts were identified which would be additional to this lower estimate (PACEC/CBR, 2009). The fact that this programme of support generated additional willingness to pay on this scale suggests that without it the 'impact' of publicly funded research would have been substantially lower. This kind of support is therefore another example of an essential complementary investment in ensuring impact occurs.



## 5. The Impact of Publicly Funded Research on Output and Productivity Growth

There is an extensive economic literature that attempts to account for the role of research and development and of technological innovation in economic growth and productivity. Early growth models developing from Solow (1957) treated technical progress as essentially externally (or 'exogenously') generated and measured it as a residual effect on the growth of output after changes in capital equipment and human capital had been 'accounted' for. Depending on how these inputs were measured, these residuals could be larger or smaller and could be decomposed into various other factors due to economies of scale and so on (Denison, 1967). Critiques of this model have included early arguments that technical change cannot be easily separated from the process of investment itself as part of the introduction of new technologies and from learning-by-doing in the production process (Kaldor and Mirrlees, 1962) so that technical progress and innovation should be determined inside the model (i.e. 'endogenously'). Recent explicit attempts to 'endogenise' or build the determinants of technical change into growth models have been particularly associated with the work of Romer (e.g. 1986, 1990 and 1994).

In these more recent 'endogenous growth' models, businesses are assumed to be able to capture a substantial part of the returns to their investment in innovation (i.e. markets are not perfect, and not all knowledge spills over freely). There is thus an incentive for firms to conduct their own R&D as part of their own growth strategy, and this contributes directly to innovation and productivity growth. There are also spillovers, however, and so private R&D has additional 'public' benefits, yielding yet more innovation and productivity for other firms. As a result, overall growth is related to the proportion of resources including human capital devoted to R&D and other innovation-related activity and the stock of past accumulated knowledge (see e.g. Fagerberg, 1995, for a synthetic overview of these and earlier models).

### 5.1 *Economy Level Studies*

The majority of studies based on endogenous growth theory (Romer, 1986, 1990 and 1994; Lucas, 1988; Grossman and Helpman, 1991 and 1994; Aghion and Howitt, 1995) suggest that a key role in economic development is played by technological progress and the commitment of resources to innovation. In general, studies in this vein have focused primarily on the impact of private sector R&D or R&D as a whole. These studies have typically concluded that the social return to business R&D is substantial, where the term 'social return' is used to reflect the spillovers that are generated

by innovative activities at the level of the economy as a whole. Where studies along these lines attempt to separate out the economic impact of university or publicly funded research, a large positive contribution is usually identified (e.g. Lichtenberg, 1993, Coe and Helpman, 1995).<sup>22</sup>

Two more recent macro-economic studies have attempted to disentangle the effect of public sector research more generally on overall economic output and productivity growth. The first (Guellec and Van Pottelsberghe de la Potterie, 2004) provides an analysis for 15 OECD economies in the period 1980-1998. The authors calculate measures of the total public R&D capital stock stemming from R&D performed in the higher education sector and the government sector. They estimate the long-term responsiveness (elasticity) of multi-factor productivity with respect to business R&D, to public research and to foreign R&D. The significant result from our point of view is that the responsiveness of productivity to public sector research is positive and higher than the response to private sector research (the long run elasticity, or 'responsiveness', being 0.17 for public compared to 0.13 for private). The authors conjecture that the higher return for public research at the economy level reflects the fact that publicly funded research is more concerned with basic research and is logically associated with a higher degree of spillovers in the rest of the economy, whereas private sector R&D is more likely to be concerned with applied research and the private gains are more likely to accrue to the businesses carrying out the R&D and to be captured at the firm and not the economy level.

When the authors compare changes in the responsiveness of multi-factor productivity to changes in the stock of knowledge over time, their results suggest that the impact of business R&D has been growing slowly whilst the impact of public sector research has been declining over time. They also show that the responsiveness of multi-factor productivity with respect to public sector research is higher when business R&D intensity in the economy is higher. This emphasises the complementarity of investment in the business sector to which we referred earlier. Without such investment and its implications for absorptive capacity, the ability to capitalise on opportunities arising from public research will be limited. This highlights the essential importance of considering the impact of public sector research along with complementary investments by other sectors of the economy.

Guellec and Van Pottelsberghe de la Potterie also show that the impact of public sector R&D is positively affected by the proportion accounted for by university research. This is not the case for public-sector laboratory research. They speculate that government-performed R&D may be more focused on public health, environment and defence issues, and hence is less likely to directly impinge on measured GDP growth. Public sector spending on defence has a negative impact on

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<sup>22</sup> For a brief review of studies that have included public expenditure, see Guellec and Van Pottelsberghe de la Potterie (2004).

multi-factor productivity growth whereas that on civilian R&D has a weak positive effect. A further interesting result is that the higher the share of university research financed by the business sector, the *smaller* is the impact of higher education R&D on productivity growth. The authors speculate that this may be because such research is more oriented towards the applied end and is readily captured in the returns of the individual businesses and hence is less likely to yield longer-term spillover effects at the level of the economy as a whole once those private effects are accounted for (ibid.).

A more recent study focusing on the UK alone has also produced results that suggest a positive impact for public sector R&D on multi-factor productivity growth. This emphasises in particular a positive role for university funding provided by the Research Councils. In their paper, Haskel and Wallis (2010) analyse the impact of private and public sector R&D on total factor productivity growth for the UK economy for the period 1988-2007. They find that the benefits from private sector R&D are essentially captured by the firms carrying out the research (i.e. there are not significant 'spillover' effects to overall economic growth). In the case of public sector R&D, however, there are substantial positive effects for Research Council-funded research, but no significant effects for general university funding through the Funding Councils or for civil or defence expenditure taken individually. This result is robust to varying the time-lags with which the impact is assumed to occur between one, two and three years. Haskel and Wallis also show that their positive result for the research councils holds for the period 1988-2004 as a whole and in each of a number of sub-periods ending in 2006, 2007 and 2008. The addition of later years allows a check as to whether the results are driven by the recent rapid increase in research council spending noted earlier. They find that the marginal effect of Research Council funding declines as more recent years with higher levels of funding are included in the regression.

Both these studies suggest a significantly positive impact for public sector research on overall productivity growth. In both studies, the impacts are achieved over one, two or three-year periods. These time-lags appear remarkably short, given results from more detailed case-study and industry-level research, to which we turn next.

## **5.2 The Complementarity between Public Sector R&D and Private Sector R&D**

In addition to research attempting to estimate the impact of publicly funded R&D on the rate of productivity growth, a parallel literature has developed that attempts to explore the relationship between the public and private sector R&D. On the one hand, it has been argued that funding for

public sector R&D might drive out private sector R&D, for example, by raising the price of resources required for R&D (typically skilled and highly qualified labour). Public sector R&D would then be a substitute for private sector R&D. Alternatively, as we have argued earlier, public sector R&D, by expanding the pool of available information and knowledge, could augment the extent to which private sector R&D may be expected to yield returns. In this case, the level of private sector R&D may be positively related to that in the public sector. In addition, more private sector R&D will be undertaken as a result of the greater opportunities made available by information and knowledge derived from public sector R&D. In a comprehensive review of earlier work, David et al. (2000) concluded that the findings of previous analytical work on this relationship were ambiguous. They pointed to the difficulty of comparing results using different methodologies across different countries, and also highlighted the extent to which the overall pattern of findings may be biased by the predominance of US studies in the overall literature in this area. A number of more recent studies based on newly emerging evidence on university-industry relationships and others covering a range of European countries have produced a more positive interpretation. Cohen et al. (2002) use data from the Carnegie Mellon Survey on Industrial R&D for the US manufacturing sector to assess the influence of university and government R&D labs on industrial R&D. They conclude that public research is critical to industrial R&D in a small number of industries, and that it has important effects across a much wider range of manufacturing sector R&D. These impacts arise from both the development of ideas for new R&D projects as well as the completion of existing ones. New business start-ups and larger firms are particularly influenced by these relationships. This study also emphasises that the key pathways by which impact occurs includes publications, conferences and a range of activities regarded as central to core university roles.

Jeaumotte and Pain (2005a and 2005b) analyse data from innovation surveys and from national and sectoral accounts for a large sample of OECD countries, and provide evidence consistent with a positive impact of public sector R&D on private sector R&D. They also report positive impacts on innovation performance and patenting activity. In one paper, Jeaumotte and Pain (2005a) use panel data regression techniques to analyse the effects of innovation policies and broader framework factors on business R&D intensity and patenting for a sample of 20 OECD countries over the period 1982-2001. They show that non-business R&D as a whole and business funding of non-business R&D both have a positive influence on business R&D intensity at the economy level as well as on patenting performance. This strongly reinforces the hypothesis of complementarity between business and public sector R&D. In another paper, Jeaumotte and Pain (2005b) analyse the determinants of innovation performance across countries as measured directly by European Community Innovation Survey indicators such as the proportion of innovating firms in the economy



and the proportion of sales due to innovative new products as well as R&D in patenting activity. They include public sector R&D amongst their determining factors and conclude that

“...research in the non-business sector is an important component of innovation, both directly, as reflected in patenting, and indirectly through its wider effects on private sector activities. Even though an expansion in public sector research can help to push up wage costs for the business sector, this is more than offset by a positive impact on the labour efficiency of business sector researchers. An increase of 1 standard deviation in the share of non-business R&D in GDP (an increase of 0.06 percentage points for the average economy) raises business sector R&D by over 7% and total patenting by close to 4%.” (ibid., p.38)

In a similar vein, Cincera et al. (2009) develop an empirical methodology for assessing the efficiency of the main policy instruments open to government to support R&D activities in the private sector. They distinguish between direct subsidies and tax incentives as supporting policies alongside R&D performed in the public sector. They also distinguish between the higher education and government sectors. They use both parametric and non-parametric methods including data envelope analysis and stochastic frontier analysis to assess the efficiency with which support measures are reflected in R&D performance. In relation to their stochastic frontier analysis, they report that higher education expenditure on R&D has a positive impact on private sector R&D and on the number of R&D personnel employed in the business sector. This is consistent with the results of Jeumotte and Pain discussed above. This study also categorises countries in terms of the efficiency of their conversion of public support for R&D into economy-wide performance with regard to innovation and patenting. On this basis, the UK is in a middle group of average performers along with France, Hungary, Italy, Korea, Norway, Sweden and Spain. The top performing group includes Australia, Canada, Finland, Germany, Japan, the Netherlands, New Zealand, Singapore, Switzerland and the USA.

By themselves the econometric results linking public sector R&D to output and productivity growth tell us very little about the process by which these impacts occur. They also depend heavily on assumptions about the weights to be attributed to the inputs of capital, labour and knowledge stocks in deriving productivity estimates, and on the particular form of the functional relationship between inputs and outputs.

### 5.3 *Impact Evaluation in Specific Sectors or Fields of Research*

There have been a number of attempts to estimate the impact of public sector funding on the public sector conduct of R&D at the level of individual sectors or fields of research. These are reviewed extensively in Martin et al. (1996), Salter et al. (2000), Salter and Martin (2001), Scott et al. (2002), and Martin and Tang (2006).<sup>23</sup> Many of these studies were US-based, with the early ones often being concerned with agricultural research. They yielded rates of return to public R&D expenditure of typically between 20% and 67% (Salter and Martin, Table 2, p.515). This is a very substantial impact for public sector R&D in those specific industry or country cases. In the industry studies reviewed in Salter and Martin (2001) calculating estimated rates of return to publicly funded R&D, the effects occur with long and variable time-lags. Although these time-lags appear to be shortening over time, they still fall within the range of six to 15 years. None of these relate to the UK. Studies at the industry level, moreover, indicate that there are very wide variations in the ways in which, and the rate at which, knowledge is exchanged between the publicly funded research sector and private enterprise. One possible explanation for the disparity in the time-lags between the macro and industry-level studies is that the latter frequently focus on transition paths from basic scientific discoveries. If public sector R&D includes substantial problem-solving or more applied development activities, and raising the stock of R&D is associated with higher levels of such activity, then the macro studies may generate ‘impacts’ over shorter time periods. This issue is worthy of further research.

In contrast to studies covered by the earlier reviews listed above, many of the more recent studies have focused on the economic benefits of biomedical and health research. For example, Silverstein et al. (1995) estimated that for every dollar invested in medical research in the US, there has been a return of at least three to one in the form of savings from hospitalisations avoided, from productive work gained, and from medical procedures not required as a result of drugs or technologies arising from research. Reports prepared for the Lasker Foundation (Lasker, 2000) and for Australian Society for Medical Research (Access Economics, 2003), both of which claimed to find “exceptional returns”, various studies reported in a book edited by Murphy (2003), and work by Murphy and Topel (2003) all claim very substantial returns from medical research, typically of between three and eightfold, depending on the area of medical research (see also the review in Rosenberg, 2002).<sup>24</sup>

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<sup>23</sup> See also PA Consulting and SQW Consulting (2007), which provides 18 case-study impact reviews for the UK Research Councils spanning the (then) eight Research Councils. These are structured using the Treasury Impact Model framework but do not attempt systematic internal rate-of-return or cost-benefit calculations.

<sup>24</sup> This paragraph draws extensively upon Martin and Tang (2006, pp.9-10).

These studies continue to be very popular in the US, not least because of the perceived need to justify the huge annual investment by the Federal Government in the National Institutes of Health (NIH) of some \$25-30 billion or so a year. For example, Johnston et al. (2006) calculated that medical research trials funded by the NIH at a cost of \$335 million are likely to yield an additional benefit to society after 10 years of \$15.2 billion. In the last year alone, there have been three further studies. In one, Ehrlich (2011) estimated that the NIH investment of \$26.6 billion on research awards in 2010 “produced \$68.035 billion in new economic activity” (ibid., p.1). Similarly, Umbach (2011) calculated that each dollar invested in research at US medical schools and teaching hospitals resulted in \$2.60 of economic activity, although this figure does not include less direct economic benefits such as saved lives and improved quality of life nor other ‘downstream’ economic benefits. In a third study by the Battelle Technology Partnership Practice (2011) of the economic impact of the Human Genome Project (HGP), the authors concluded that “every \$1 of federal HGP investment has contributed to the generation of \$141 in the economy” (ibid., p.ES2). This incredibly high return on investment (ROI) of 141 to 1 points to a central problem with approaches such as this with their claims of truly ‘exceptional returns’ to medical research, namely the problem of attribution. None of the claimed economic benefits identified in such studies flow *solely* from the initial biomedical research – there are numerous other contributing factors. Identifying exactly what proportion of the ultimate economic benefit should be attributed to the earlier biomedical research involves making a number of truly heroic assumptions that are open to challenge.<sup>25</sup>

In contrast to these approaches to sector level analysis alternative wider ranging approaches have been proposed. These use payback frameworks and other ‘bottom-up’ and tracking assessment techniques to assess impact. This relates closely to the point raised earlier in this review about the complexity of innovation pathways and the multiple complementary investments required. These approaches also help to reveal the specific processes involved in the evolution of an innovation and the form and scale of impacts produced. They have again been used predominantly in relation to medical research and innovation, although a number of examples can also be found in relation to the UK research council funding in engineering, biological sciences the arts and humanities and the social sciences.

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<sup>25</sup> There is also a significant danger of sample selection here, as funders and their agents select successful programmes or activities for assessment. It seems scarcely credible that every research programme generates substantial let alone ‘exceptional’ returns. This highlights the need for evaluators of impact to be clearer about their methods and to establish more robust, systematic approaches that allow for comparisons across countries and programmes. At present, research impact evaluation appears to be something of a ‘black art’, with a number of private consultancies operating with only partial disclosure of methods and raw data (Ammon Salter, private communication).

### 5.3.1 UK Health Research

One prominent example is the 'payback framework' first developed by Buxton and Hanney (1996) and subsequently extended in various assessments (e.g. Buxton et al., 2000; Hanney et al., 2004). In recent years, these two authors and their colleagues at the Health Economics Research Group (HERG), Brunel University have collaborated with RAND Europe in a number of studies, for example, those by Wooding et al. (2009), which analyses the outputs and outcomes of research grants funded by the Arthritis Research Campaign, and by Wooding et al. (2011), which focuses on cardiovascular research.

The payback approach is a particular application of the logic model approach. Thus, for instance, in the payback model adapted for the study of arthritis research (Hanney et al., 2004), six stages are identified in the process of movement from research through to final outcomes. These stages are the inputs to research; the research process; primary outputs from the research; dissemination leading to secondary outputs in terms of policy making and product development; adaptation by practitioners; and the public and final outcomes.

It is important to note that this payback approach is very demanding in terms of the data required and that great care is necessary to produce robust estimates given the time-span over which medical research is translated into socio-economic benefits. It is also necessary to account for the very wide range of complementary investments required for the translation of research into medical applications and final socio-economic benefits. Thus, in a study of economic benefits of medical research in the UK which focused on cardiovascular disease, it was estimated that total annual funding for cardiovascular research in the UK from public and charitable sources amounted to just over £2 billion in 2005 prices. However, over the same period private sector R&D expenditure expanded rapidly and by 1992 was roughly 2.4 times as large as public sector expenditure. The result is that private sector R&D expenditure greatly exceeded public plus charitable expenditure in this domain. (Health Economics Research Group et al., 2008, pp.16-19). In addition to these significant complementary investments, the delivery of healthcare also involves incremental costs associated with patient care. In the period from 1985 to 2005, this amounted to £15.6 billion.<sup>26</sup>

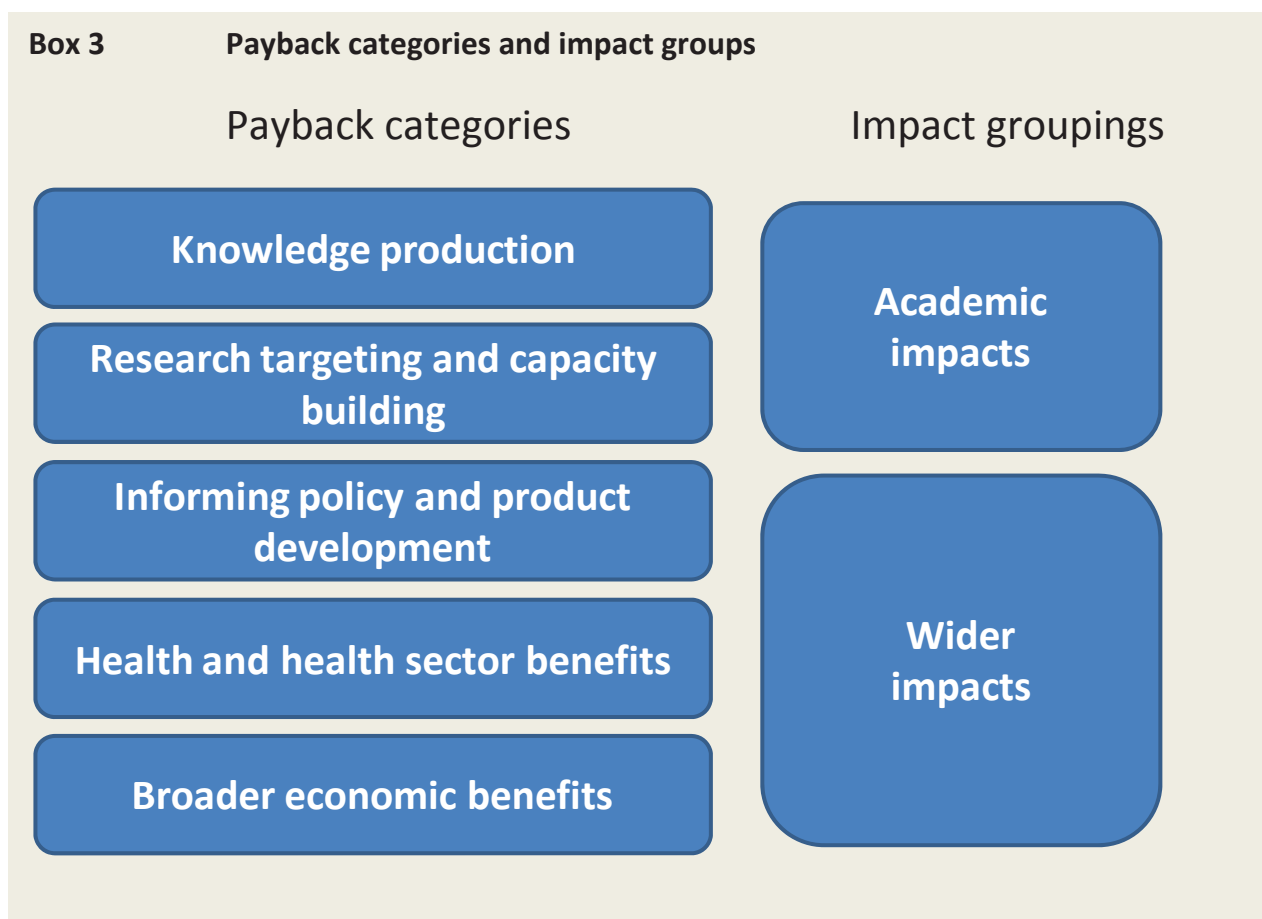
These analyses typically have at their core detailed case-study narratives yielding a variety of qualitative and quantitative output or payback indicators at each stage of the transition from

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<sup>26</sup> All of these cost estimates are based on a careful sensitivity analysis and are the mid-value estimates between upper and lower bounds in each case. The relationship between cardiovascular disease research in the period 1975-1988 is related to health benefits and their costs in 1992-2005 because the investigators' best evidence-based estimate of the length of time it takes from research to treatment is 17 years (Wooding et al., 2011).

research projects through to publications and other process outcomes and ultimately to health care effects. They typically do not attempt to calculate net present value or internal rates of return based on overall healthcare or wider economic impacts. Instead, rich interpretive and policy conclusions are drawn on the basis of understanding causation and process, and on careful calibrated comparisons across cases. In Wooding et al. (2011), for example, the payback approach is used in a case study based review of 29 cardiovascular and stroke research grants funded in three countries, including the UK, between 1989 and 1993.

Using the framework in Box 3 below, the authors focus on academic paybacks (knowledge production, capacity building and research targeting) and wider paybacks (informing policy and product development, health and health sector benefits, and broader economic benefits). They use a variety of carefully moderated Likert-type scales to measure the dimensions of payback success across different types of project in terms of basic versus clinical orientation scale and type of grant.



Source: Wooding et al. (2011).

In keeping with many studies in the wider innovation literature, Wooding et al. (2011) find that the majority of the wider economic impacts identified come from a small minority of projects. They also show that basic biomedical research has, as might be expected, a greater 'academic' impact, whilst clinical research has a bigger effect on 'wider' impact. Knowledge production *per se* does not appear to be a good predictor of 'wider' impacts. Thus, the study found no correlation between the payback category of knowledge production and the three 'wider' categories of informing policy and product development, health and health sector benefits, and broader economic benefits. However, the authors did find that basic biomedical research with a clear clinical motivation was associated with both high academic impact and with wider impact, and that the location of basic biomedical research in a clinical setting was also positively associated with 'wider' economic impact, as was strategic thinking by clinical researchers. Finally, engagement with practitioners and patients and collaboration with industry were also associated with both high academic impact and wider impact. The connection of these findings to the Pasteur's Quadrant analysis of user-inspired basic research discussed earlier seems clear.

The payback framework has also been used in an attempt to derive final impact measures in terms of rates of return. Thus, Health Economics Research Group et al. (2008) estimate the returns to UK public and charitable medical research in cardiovascular and mental healthcare. This study is valuable in many ways, not least in the transparent way that the data and assumptions required to obtain quantitative estimates are discussed. The study makes extensive use of upper and lower bound estimates at various stages of the calculations, and builds up the assessment of health care benefits from specific domains of cardiovascular health care interventions. Since health care in the UK benefits from research worldwide in both the public and private sector, the authors are also careful not to claim all the benefits in healthcare that they identify as attributable to UK public and charitably funded research. They judge (on the basis of a review of relevant literature and research cited in UK clinical practice guidelines) that the proportion of UK health care benefit attributable to UK publicly funded research lies in the range from 10% to 25%, with a central estimate of 17%, and that the impact occurs with an estimated time-lag of between 10 and 25 years, with a central estimate of 17 years.

The authors then compare the payback in terms of monetized 'quality-of-life years' attributable to UK public and charitable research with the cost of the (17 year-lagged) public sector and charitably funded research *plus* the incremental costs of delivering the healthcare. On this basis, their best estimates of the internal rate of return to public sector and charitably funded research is 9% for cardiovascular healthcare and 7% for mental healthcare. This excludes any wider economic benefit

beyond the specific health care itself. The latter might include, for example, benefits flowing from private sector R&D carried out in response to that funded by the public and charitable sectors, and improvements in other treatment areas. Assumptions are made as to the likely extent of these spillover or wider effects, which are then added to the direct healthcare benefits. It is concluded that “the total health and GDP gains to public/charitable CVD research in the UK 1975-1992 give a total IRR [internal rate of return] of around 39%. In other words, a £1.00 investment in public/ charitable CVD [cardiovascular disease] research produced a stream of benefits thereafter that is equivalent in value to earning £0.39 per year in perpetuity” (ibid., p.7). For mental health research, the estimated rate of return was similar (37% – see ibid.). It is important to note however that the ‘wider’ GDP effects account for over 75% of the estimated value of the internal rate of return. These effects are not modelled in the evaluation. Instead, the internal rate of return to this ‘wider’ GDP effect is assumed to be 30% and added to the estimated direct healthcare returns for both cardiovascular and mental health care. As the authors note in relation to the assumed wider GDP estimates, “These figures are obtained from a small empirical literature, much of it US-centred and only a proportion of it specific to medical research. Hence the application to the UK and to medical research is at best tentative.” (Health Economics Research Group et al., 2008, p.7).

The payback framework has been used in other studies including that by Raftery et al. (2009), who used it to assess the impact of the National Health Service (NHS) Health Technology Assessment (HTA) program, and in a number of countries including Hong Kong (Kwan et al., 2007), Australia (Kalucy et al., 2007), and Ireland (Nason et al., 2008). An attempt has also been made to apply it (perhaps less successfully) to UK social science and arts and humanities (RAND, 2007; Levitt et al., 2010), studies which are discussed further below.

A somewhat different approach was adopted by the Canadian Academy of Health Sciences (CAHS, 2009) in another ‘bottom-up’ approach. Like the payback model described above, it involves combining impact assessment with a logic model (Frank and Nason, 2009). It uses a set of 66 indicators and metrics to evaluate the various forms of return on investment in health research. It adopts a ‘systems approach’ to track impacts in five main categories: advancing knowledge, capacity-building, informing decision-making, health benefits, and broad economic and social benefits (including any cultural outcomes) (CAHS, 2009). The approach is designed to provide a ‘roadmap’ version of the payback model in order to help identify where different impacts occur (e.g. in the health industry, other industries, government and other decision-makers, and the public or public groups) and to follow them through various stages of adoption to final outcome in terms of improved health, enhanced well-being, and social or economic prosperity (Frank and Nason, 2009).

The impact of UK Medical Research Council funding has also been subject to a variety of evaluations, including, for example, assessments of the MRC Protein Phosphorylation Unit (PPU) at the University of Dundee and of research on DNA Technology. These were based on an MRC conceptualization of five impact pathways: professional practice and policy leading to improved patient care; benefits in terms of research tools/measures and methods; stimulation of further research; improved knowledge base for commercial R&D through publication of results; and commercialization of knowledge (e.g. spin-outs, IP). Case-study evaluations translating these into Treasury Logic Model form demonstrated a wide variety of outputs, outcomes and impacts without attempting rate-of-return estimates. These included, in the case of PPU, royalty income of £1.1 million annually, leveraged private sector co-funding of £23.4 million, and public-private sector investment of £50 million in the Dundee biotech cluster, along with major publication and student-training impacts. These relate to an MRC funding input of £16 million. In the case of DNA Technology, in addition to a wide range of research outputs, the research produced several families of patents and two spin-out companies, one of which was capitalized at \$160 million (PA Consulting Group and SQW Consulting, 2007, Part II, pp.206-234).

### 5.3.2 Social Science Research and Policy Impacts

The ESRC have carried out a number of evaluations of individual projects, programmes and research centres. These have employed qualitative and quantitative methodologies. None of them have been designed to produce rate-of-return calculations. They reveal a variety of substantial impacts based on qualitative assessments and a range of quantitative estimates using different valuation metrics.

In an analysis of the impact of the Centre for Economic Performance (CEP) and the Centre on Skills, Knowledge and Organisational Performance (SKOPE), an effort was made to combine qualitative case-studies with quantification of the transmission mechanisms leading to policy impacts in terms of books, journal articles, discussion papers, dissemination, events and PhD training.<sup>27</sup>

The qualitative research based on interviews suggested that there had been a significant policy influence of ESRC-funded research through CEP, for instance in relation to the introduction in the UK of the National Minimum Wage. Imputing an economic value to this impact was, however, extremely problematic. The overall impact of the introduction of the National Minimum Wage had

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<sup>27</sup> In relation to the evaluation of books, attempts were made to calculate an economic value based on usage and sales data. For discussion papers, efforts were made to estimate value in terms of the cost of production. Proxy values for events were based on making assumptions about the number of attendees and the estimated cost of the time spent by them in attending a meeting. In addition, a proxy economic value was placed on PhD degrees awarded through the research centres and on journal articles.



not been subject to an overall economic evaluation, so no reliable estimate of the net economic benefit generated by the policy itself was possible. Based on an estimate of the number of workers benefiting from the introduction of the minimum wage, the impact on the wage bill was estimated by the assessment team at between £1.2 billion and £1.4 billion. Using the £1.2 billion figure, the assessment team argued that “even if only 2% of the growth benefits is attributable to CEP, that equates to £24m”. The ESRC share (based on the proportion of CEP revenue that they accounted for) would hence be £9.6 million (Frontier Economics, 2009, p.22).<sup>28</sup>

There are a number of problems with this kind of estimate that the report itself recognises. First, the impact of the National Minimum Wage on the wage bill itself is a calculation that does not take account of any counterfactual (i.e. what would have happened to the wages of the low paid today if there had been no national minimum wage). Similarly, there is no particular basis for choosing the figure of 2% of the gross benefit supposedly attributable to CEP. It is therefore difficult to disagree with the other conclusion of the report that “it is impossible to attribute with any precision the value generated by CEP” (Frontier Economics, 2009, p.22).

In the case of SKOPE, the qualitative research again confirmed that there had been significant influence on key areas of policy development. However, the review was unable to place an economic value on the impact that SKOPE had had because of the difficulty of linking skills research to a specific policy or programme. They also noted that in one particular case where it might be possible to get such measures, it was not possible to do so because the underlying programme to which the research had contributed had not been subject to a complete evaluation.

In a review of three centres concerned with innovation (the ESRC Centre for Research on Innovation and Competition (CRIC), the ESRC Centre for Organisation and Innovation (COI) and the ESRC Complex Product Systems Innovation Centre (CoPS), a logic chain analysis was adopted based on the Treasury *Green Book* approach discussed earlier.<sup>29</sup> The report (Pricewaterhouse Coopers 2008) identified two core impacts. The first related to an enhanced skill base arising from education and training of students, especially at post-graduate level. The second was the potential impact on public services, including policy formulation, which could lead to productivity and economic benefit across the public and private sectors. The report estimated a gross lifetime value of the PhD students and

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<sup>28</sup> Similar difficulties in attributing policy impacts are identified in an evaluation of the ESRC-funded Centre for the Analysis of Social Exclusion, where it is concluded that ‘the model of how social research impacts on public policy is diffuse and unclear’. The evaluation therefore confines itself to identifying ‘potential’ impacts on the views of stakeholder groups arising from ‘direct influence’ and ‘general enlightenment’ (PA Consulting Group and SQW Consulting, 2007, Part II, pp.184-185).

<sup>29</sup> The evaluation involved, in addition, an analysis of the literature and reports associated with the centres, a series of interviews with the directors and research staff, and a telephone survey of 40 direct users of the research outputs, followed by a further four in-depth interviews (Pricewaterhouse Coopers 2008)

MSc students associated with the three centres of the order of £8 million. The report noted that there were major difficulties in establishing unambiguous links between the activities of a centre and particular policy changes, and further difficulties arising from assessing economic impacts in terms of whether the policy itself yielded net benefits (*ibid.*).

In an analysis of the impact of the ESRC Centre for Business Research (CBR) at the University of Cambridge, INGENIO (2007) used the 'follow through' or 'tracking forward' approach. This tracked specific research outputs and projects through to use and impacts. The evaluation report based its conclusions on a qualitative interpretation of a series of in-depth interviews and analysis of the mechanisms used by the CBR to interact with policy and business practitioners. It concluded that there had been significant policy and practice impacts generated by the CBR. This included particular contributions to the Law Reform Commission's deliberations on the Law relating to Directors Duties; the development of personal bankruptcy insolvency laws, an impact on UK labour market policy (including work related to the minimum wage and new rights for trade unions), and finally work in relation to the development of a consistent panel dataset on small and medium-sized enterprises. The latter arose through the National Small and Medium-sized Business Survey conducted on a biennial basis by the CBR. The evaluation concluded that these datasets had provided an extremely valuable resource for researchers, academia, government and private industry. The data had been used for confirming and informing policy on SMEs' attitudes, the impact of government policy and concerns over financial support. Private sector companies and banks had also used the dataset to cross-check their internally generated data on SMEs and to inform their policies on credit support for smaller businesses. The report did not attempt to economically quantify the benefits.

An evaluation of the ESRC Future of Work (FOW) Programme used a 'tracking forward' methodology linked to a payback framework structure. This identified five impact categories: knowledge; impacts on future research; impacts on policy; impacts on practice; and wider social and economic impacts (RAND, 2007).<sup>30</sup> The evaluation concluded that there was strong qualitative evidence of influence arising from general understanding based on the research on a wide range of policies. They reported considerable difficulty in isolating specific impacts and in particular the link to specific projects, and noted that influence was frequently connected with key networked individuals and appeared most effective when conducted through secondment. The iterative incremental nature of policy development, limited access to politically sensitive material and a lack (compared to biomedical research) of mechanisms to codify and synthesize research in social and policy research hindered the identification of specific impacts (*ibid.*). Again, no attempt was made to quantify impact.

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<sup>30</sup> The programme included 27 individual research projects. The empirical methodology used included interviews, four case studies and online surveys.

In contrast, a 'tracking back' approach to impact was adopted in assessing the impact of ESRC research on the Sure Start initiative, which was introduced in 1999 with the aim of providing integrated early-year services for disadvantaged groups. The tracking back approach sought to identify the key research findings in publications that could be demonstrated to have had an impact on key decisions made with regard to the Sure Start policy. Within that, the role played by the ESRC in supporting the research that underpinned Sure Start was also evaluated. The evaluation consisted of a review of existing research that had described and analysed the contribution made by social research in this context. It also involved interviewing a number of key individuals to establish their views on the history of the initiative and to pinpoint relevant research findings and publications. The report concluded that "social research played a very important role in the decision to establish the Sure Start programme in 1998" (Johnson, 2011, p.19). However, it also noted that it was less clear whether subsequent policy and operational decisions related to Sure Start were linked to the evidence base arising from social science research. The evaluation was unable to provide precise quantification of the impact of the research in terms of what were the estimated outcomes of the policy initiative. Moreover, ESRC-funded research *per se* appeared to have played a limited role in the process of policy introduction or development subsequent to the initial introduction of the policy. The report nevertheless emphasises the importance of ESRC dataset creation in supporting policy-relevant research that had influenced policy (*ibid.*). Thus the 1958 and 1970 birth cohort studies ensured that there was both an important dataset underpinning the research associated with introduction of the policy and the development of appropriate analytical skills to use the data for research purposes. The ESRC's co-investment with governments departments in the Millennium Cohort Survey (MCS) played a similar role.

The MCS has itself been the subject of an impact evaluation. In this case, a tracking forward approach was adopted. The research involved a review and synthesis of existing background literature and policy documents. It also included a consultation stage, involving interviews with key individuals involved in communication and marketing at the Centre for Longitudinal Studies (CLS) and the Economic and Social Data Service (ESDS) along with stakeholders in government research institutes and elsewhere. The report noted that the impact of the MCS occurs within a complex non-linear process through which policy and practice are related, and therefore there is no clear process which leads directly from the MCS to policy or practice (ESRC, 2011).

The report suggests three kinds of impact where the MCS can be identified as having made a contribution. The first is 'instrumental impact', a proxy indicator of this being explicit mentions in policy and related documents of MCS data providing supporting evidence. A second is 'conceptual

impact’, where research outputs that have used MCS data have enhanced understanding and informed policy debate. The third is ‘capacity-building impact’, in the form of the development of the UK’s skills base in longitudinal analysis through using the data. The report also noted the role of various intermediary organisations such as think-tanks and lobby groups in developing and informing the policy debate. In addition, the report pointed out that, insofar as impact depended on the use of the longitudinal datasets, an important potential constraint on impact could arise from a lack of relevant skills in user organisations (ESRC, 2011).<sup>31</sup>

### 5.3.3 Innovation and Commercialisation Impacts in Engineering, Physical Sciences, Biotechnology and Biological Sciences

A large variety of research council impact assessments have been carried out covering the engineering and natural sciences in the UK (de Campos, 2010). Few produce rate-of-return calculations. Several report a variety of quantitative metrics in addition to qualitative findings.<sup>32</sup> The Engineering and Physical Sciences Research Council (EPSRC) commissioned an economic impact assessment of its Innovative Manufacturing Research Centres (IMRCs) (EPSRC, 2011a). The IMRCs represented a very considerable EPSRC investment. They were established in 2001 and total EPSRC funding in 15 IMRCs over the following 10 years amounted to £192 million. The evaluation was based on an analysis of 32 projects in eight centres. The projects accounted for 9% of total EPSRC funding for the IMRCs. The case-studies identified gross impacts in a number of dimensions. In terms

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<sup>31</sup> Other approaches to evaluating ESRC research have focused on the disciplinary fields of politics and international studies (PPG, 2007) and management research (PA Consulting and SQW Consulting, 2007, Part II, pp.191-204). The first identified non-academic references to the academic publications of a wide sample of ESRC ‘responsive mode’ research grant recipients. This was combined with interviews with academics about their assessments of the nature of the impact of their work, based on views covering the period of the grant itself and a more contemporaneous assessment at the time of the interview. A subjective interpretation of the combined bibliometric and qualitative interview data was then used to identify a small number of the overall portfolio of responsive-mode projects completed in 1998 and 2001 which, in the assessors’ views, had had significant impact. No attempt, however, was made to assess or quantify the specific contribution to overall policy development or the economic impact of the policy development itself. In relation to management research, a case study of the Advanced Institute of Management (AIM) initiative used interview assessments, citations in policy documents, and qualitative examples of changed businesses practices as a proxy for impact but again produced no quantitative estimates of the actual effects. A hypothetical quantitative illustration was instead attempted. This was based on AIM researchers having a variety of interactions with 36 of the FTSE Top 100 companies, and then making a series of rather arbitrary assumptions in order to estimate the impact. The annual growth in turnover for those firms at the time of the evaluation was estimated at £39.2 billion. On the assumption that 10% of the firms benefitted from the AIM interaction and that between 0.1% and 0.5% of their sales growth could be attributed to the interaction, this yielded an annual estimated impact of between £4 and £20 million compared with the total AIM programme cost of £25 million (PA Consulting and SQW Consulting, 2007, Part II, p.204). The weight that can be placed on such an estimate is probably not that great.

<sup>32</sup> PA Consulting Group and SWQ Consulting (2007) carried out ten case-studies of the impact of physical and natural sciences research funded by: the Biological and Biotechnology Research Council (BBSRC) covering Animal Health and Biomolecular Sciences; the Central Laboratory of the Research Councils (CLRC) covering the use of lasers and protein crystallography; the Engineering and Physical Sciences Research Council (EPSRC) covering the EngD programme, polymer science and Foresight challenges; the National Environment Research Council (NERC) covering ocean margins; and the Particle Physics and Astronomy Research Council (PPARC) covering studentships, and detector research applied to medical imaging. They also provide cross-council case-studies covering the Tyndall Centre and Applied Genomics.

of improvements to existing businesses associated with the projects, the study identified the following: the creation of 160 new jobs and the safeguarding of 230 more; £70 million of additional sales; significant increases in market share; 20 new technologies or products introduced to the market; licensing fees of £43 million; and cost savings of £10 million. In addition, eight spin-outs in the UK were created as well 11 spin-outs overseas. The EPSRC investment also directly leveraged research support of £1 for every £1 invested by EPSRC, amounting to £12.75 million in the 32 project case-studies carried out. A number of wider environmental, public policy and service benefits were also identified, as well as human capital gains in terms of staff and students recruited into industry, the development of course supervision of PhDs or EngDs by industry, and involvement in Knowledge Transfer Partnerships and Knowledge Transfer Secondments. Taking the scheme as a whole, and building on the 32 case-studies of impact arising in the IMRCs, a conversion to net impacts was made on the basis of a number of specific and challengeable assumptions, in particular that there would be small overseas leakage effects as the collaborating businesses had a strong UK presence, and that there would be low displacement effects since the early-stage nature of the investments meant that companies were unlikely to be investing in this area in their own right so there would be very little 'crowding out' of private sector investment by IMRC activities. The selected case-studies suggest that between 20% and 50% of the impact can be attributed to the work of the IMRCs, with the remainder relating to pre-IMRC work and the involvement of collaborators and other parties or funders. On this basis, the evaluators concluded that the net impact can be estimated at between five and 13 times the initial EPSRC investment (EPSRC 2011a).<sup>33</sup>

A study commissioned by the Engineering and Physical Science Research Council (EPSRC) and the Royal Society of Chemistry attempted to assess the economic impact of chemistry research in the UK. A distinction was drawn between 'upstream' and 'downstream' sectors in terms of upstream sectors producing chemicals and downstream sectors using the outputs of upstream sectors. On the basis of case studies and interviews, the evaluators state that "the upstream chemical industry is assumed to be 100% dependent on fundamental chemistry research" (Oxford Economics, 2010, p.18). The report also notes that "While it is not possible to isolate the impact of UK-based fundamental research in this conclusion, it is clear from the consultations that the academic base is highly significant in delivering the research needed by businesses operating in the upstream sector" (ibid., p.19). On that basis, an analysis is then made of the economic impact of upstream and downstream chemistry-dependent industries. That economic impact is then attributed to chemistry research. No attempt is made to separate the impact of publicly funded chemistry research in this

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<sup>33</sup> The summary final report unfortunately does not contain details of how the economic impacts were derived from the case studies.

analysis. The report nonetheless contains numerous examples of the translation of research into applications and the important distinction between the relative dependence of upstream chemistry-based industries on more fundamental or basic research and “the use of fundamental principles of chemistry to tweak existing product to meet more immediate needs” in downstream applications. (ibid., p. 25). A similar study of physics used the same kind of approach. On the basis of the classification of industrial sectors in terms of their dependence on physics, a comparison is made of a number of economic indicators of the differences between physics-based and non-physics-based sectors. There is no breakdown of public and private sector support for physics research nor any direct attribution of the performance of physics-based sectors to the underlying research base (Oxford Economics, 2009).

The Biotechnology and Biological Sciences Research Council (BBSRC) commissioned an evaluation of UK-based *Streptomyces*<sup>34</sup> genetics research. The evaluation included a number of economic impact indicators as well as a social and qualitative analysis of the wider impact of *Streptomyces* research. This included capacity-building through the training of PhD students and the creation of spin-out companies related to activities undertaken at the John Innes Centre (JIC), which played a central role in the research programme. The evaluation provides an overview of key milestones in the evolution of research in *Streptomyces* genetics over a 50-year period. This reveals the extensive international scientific effort involved in the development of research in this area as well as the relative importance of the role played by UK research and JIC in particular. The analysis focuses on BBSRC funding for the period 1997-2009, which amounted to £31.5 million in money terms. The report notes that the *Streptomyces* Genome Project was completed in 2001, but it generally takes at least 15 years to bring new drugs to market, so the bulk of impacts would not have occurred by the time when the evaluation took place. The impacts derived are therefore based on arguing back from estimated market sizes to estimated impacts based on assumptions of what percentage of estimated market values might be accounted for by new products. A typical conclusion is as follows: “if *Streptomyces* research supports the development of a substantial number of new anti-bacterial products, new revenue streams will be created in this market. Even a very conservative increase of 1% would lead to additional sales revenue potential of \$370m (£247m) per year as a result of *Streptomyces* research” (DTZ, 2010, p.13). “It is likely that global pharmaceutical firms will take forward *Streptomyces* discoveries to develop new products for both anti-cancer and immunosuppressant drugs. On the basis of Doxorubicin<sup>35</sup>, these annual sales are likely to exceed

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<sup>34</sup> *Streptomyces* bacteria are a source of compounds that have been used in the development of anti-bacterial, anti-fungal and anti-cancer drugs.

<sup>35</sup> Doxorubicin was a drug developed in the 1960s and it is used to treat a variety of cancers.

£120 million per annum in the long term.” Whilst these assumptions may or may not be reasonable, they are not based on any assessment of actual impacts, making it difficult to be confident in any estimated return on investment.

The evaluation identified five spin-out companies, one of which had been subsequently bought by a major multinational for \$190 million and another which had secured a licensing agreement with an international pharmaceutical company worth \$295 million. A third had achieved £13.1 million in funding and at the time of the evaluation employed around 30 people.

A qualitative analysis in terms of career paths of alumni and the role of JIC in relation to scientific capacity through PhD and peer group research training also indicated a significant impact associated with the research.<sup>36</sup>

Both STFC and NERC have commissioned evaluations of the impact of aspects of their research. For example NERC 2006 focuses on 10 case studies and documents a wide variety of qualitative and strategic impact indicators. The NERC cases chosen were Terrestrial Initiative in Global Environmental Impact Research; Rapid Climate Change; Global Nitrogen Enrichment; Urban Regeneration and the Environment; Marine and Freshwater Microbial Diversity; Environment and Human Health; Lowland Catchment Research; The Flood estimation Handbook; Geo-report and Subsidence Information; Discovery of Hole in the Ozone Layer. The estimated wider social and direct economic impacts of the cases studied were evaluated using the HM Treasury Green Book logic model and were based on 80 interviews with various stakeholders to generate substantial estimated *potential* rather than actual benefits. The STFC 2006 study focused on the social and economic impact of the Daresbury Synchrotron Radiation source over the period 1981-2008. The study provides an in-depth analysis of the multiple pathways to impact internationally and nationally and an estimate of the gross impact on the local economy of 229 jobs supported per year and a total local financial impact (including multiplier effects for local spending) of £992million (STFC 2009 p120).

#### 5.3.4 Arts and Humanities: Assessing Impact

The arts and humanities cover a wide range of disciplines. These include media studies, drama, music and design, architecture, history, classics, archaeology, philosophy, religion, English literature, modern languages, linguistics, and law. There is consequently a wide range of potential impact

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<sup>36</sup> For further evaluations of BBSRC research, see the case studies of The Institute of Animal Health and of bio-molecular sciences in PA Consulting Group and SQW Consulting (2007, Part II, pp.37-72).

pathways corresponding to this diversity, and the employment histories of PhD students and Masters students in the arts and humanities display a very wide range of career paths (AHRC, 2006a and 2006b).<sup>37</sup> One approach to this diversity has been to use, as a proxy for the value of impact, data on the value of overseas educational fees earned. Here, the argument is that funding is essential to maintain the high international reputation of the arts and humanities, and that this is reflected in the extent to which overseas undergraduates and post-graduates are attracted to the UK. It has been estimated that the value of such inward flows in 2007-8 amounted to between £2.5 billion and £3.29 billion (AHRC, 2010, p.11).<sup>38</sup>

There are a large number of individual narratives and qualitative cases describing arts and humanities impacts in a range of areas (e.g. arts and design, the performing arts, cultural exhibitions, the broadcast media, forensic archaeology, forensic linguistics, and human rights law – see Hughes et al., 2011a; AHRC, 2010 and 2011). There have also been a number of attempts to carry out evaluative assessments. Levitt et al. (2010), for example, carried out a questionnaire survey and interview programme to evaluate the impact of arts and humanities research at the University of Cambridge. In addition to arts and humanities researchers and senior administrators in the University, interviews were conducted with external users of research, and four case studies were carried out using the payback framework (developed by HERG in relation to health research and discussed earlier in this report). The standard payback framework employed was modified to alter the categories of impact, and to introduce teaching as a specific pathway to impact in the model. Examples of impact paybacks which were identified include the production of bestseller books<sup>39</sup>, the use of research to inform and develop professional practice, and presentations and interviews involving the mass media and cultural events. Although the case studies reveal a wide variety of such examples of payback at various stages of the process, the report concludes that there is great difficulty in attributing impact to arts and humanities research in general and to particular research projects. The authors attribute this to the cumulative nature of research advances in the arts and humanities. They also identify very long time-lags between the conduct of research and evidence of impact. It is not clear, however, why these difficulties should be seen as particularly specific to arts and humanities.

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<sup>37</sup> For a comparison of academic interactions with external organisations *within* the Arts and Humanities, and also for a comparison *between* the Arts and Humanities and other disciplines, see Hughes et al. (2011a).

<sup>38</sup> This is based on taking the overseas student income in terms of tuition fees and living costs, and applying either the Universities UK income multiplier or an income multiplier attributed to PricewaterhouseCoopers (PwC) to the raw data (both of which are designed to capture second round and later spending and income effects generated by the initial direct income effects (AHRC, 2010, p.11).

<sup>39</sup> For an attempt to estimate impacts relating to book publication linked to AHRC funding, see PA Consulting Group and SQW Consulting (2007, Part II, pp.22-32), which contains a good description of the difficulties involved.



A more central difficulty is perhaps accounting in conventional 'value for money terms' for the pervasive socio-cultural impacts of arts and humanities research. Arts and humanities impact involves, it is argued, assessing the maintenance and growth of civic as well as economic capital. Such research enhances understanding of, and contributes towards, the social and cultural norms that help to define individual and national identity and the nature of relationships within particular national, regional or ethnic networks and social milieux (AHRC, 2010 and 2011). However, it is possible to attempt to place an economic value on at least some aspects of civic capital. For instance, it has been estimated that exhibitions associated with an AHRC-funded research project on "Polynesian Visual Arts: meaning and histories in Pacific and European cultural contexts" attracted over 21,000 visitors in Norwich and 120,000 in London. From visitor expenditures (calculated using data on how far they had travelled to visit the exhibitions and their motivations for travelling), an estimate was obtained of average daily and overnight spending by visitors based on data from the UK Tourism Survey. A multiplier was then added to capture secondary impacts arising from exhibition visitor-related expenditure beyond the exhibition per se, and appropriate additionality adjustments were made. The economic benefit was estimated to be £8.1 million for the UK economy, £3.9 million on the London economy, and £270,000 on the Norwich regional economy (PwC estimates, cited in AHRC Impact Strategy, 2007).<sup>40</sup> Grossing up a variety of such estimates, the AHRC estimated that the total economic impact of exhibitions from AHRC awards for 2006-7 "could be as much as £210.6m" (AHRC, 2010, p.34).<sup>41</sup>

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<sup>40</sup> Similarly an analysis of the AHRC-funded Surrealism Centre suggested that a single exhibition produced as part of its programme impact benefits of around £1 million compared with total AHRC funding for the whole Centre programme of some £860 thousand (PA Consulting Group and SQW Consulting, 2007, Part II, pp.5-21).

<sup>41</sup> However, as AHRC itself comments in relation to the grossing-up exercise, "it is difficult to assess the extent to which the awards used as case studies for economic analysis by PwC were typical or represent AHRC awards or overall investment" (AHRC, 2010, p.35).



## 6. Conclusions

This report has reviewed the evidence relating to the impact of publicly funded research, especially UK university research funded by the Higher Education Funding Councils and the Research Councils. Such funding has increasingly been expected to demonstrate ‘impact’. However, in any attempt to assess the impact of publicly funded research, there are several important conceptual issues to be borne in mind. In particular, the exploitation of publicly funded research often depends on private sector organisations possessing the requisite absorptive capacity and complementary assets and making the necessary investment, factors far outside the control of the publicly funded researchers. Hence, the issue is not so much about isolating and assessing the impact of publicly funded research or about determining its optimal level in isolation, but more about analysing how best to understand and manage the connections between differently funded and motivated research efforts in an integrated and well-functioning *system* of knowledge production and innovation.

Previous studies have identified a number of different channels or ‘pathways to impact’ through which research in the university science base may contribute to innovation. These include: increasing the stock of useful knowledge; the supply of graduates; the creation of new instrumentation of methods; the development of new networks; university-based problem-solving and contract research; the enhancement of technological problem-solving capacity; the generation of new firms; and the provision of ‘social knowledge’. Some of these channels are more amenable to quantitative assessment of impact, others far less so, although these may be at least as important, if not more so. In addition, the time-scale to the main impact may be a couple of decades or more, long after most assessments have been carried out. Furthermore, the longer the time-scale, the greater the importance of complementary investments necessary to exploit the potential impact but the harder it becomes to distinguish the effects of the original publicly funded research from all the other factors affecting the final outcome and impact.

Studies that have attempted to come up with a quantitative measure of economic impact or rate of return invariably have to make a host of simplifying but highly questionable assumptions about the underlying nature of the links between inputs and outputs, the weights to be attached to each ‘factor’ affecting the output and impact, and the time-lags between the application of a particular input (e.g. publicly funded research) and its associated output. Instead, more qualitative approaches are needed to examine the multiple pathways through which knowledge can diffuse across organisational boundaries into commercial and economic applications.

In this report, we have reviewed a number of different types of study attempting to assess the impact of publicly funded research. These studies differ with regard to the level or unit of analysis, and the chosen method and approach and they have generated a variety of evidence regarding the estimated impact<sup>42</sup>. Studies based on bibliometric data, such as that by Elsevier, not only show that UK science performs relatively well in international terms, but also that there are strong cross-sector knowledge flows, including substantial mobility of authors between sectors, apparently transferring tacit knowledge with them. Surveys of UK academics reveal they are involved in a variety of impact pathways, most engaging in at least one or two types of impact pathway with industry, while their level of engagement with industry has been rising as the barriers to engagement have declined. Moreover, while only a small proportion of academics have been involved in 'narrow' forms of commercialisation such as patenting, licensing or forming a spin-out company, far more have engaged in 'softer' people-based forms of interactions such as consultancy, attending meetings, giving talks, and helping with problem-solving.

Surveys of firms likewise reveal a wide variety of forms of engagement with universities in order to obtain access to state-of-the-art research, to problem-solving skills and to R&D facilities. However, among the barriers encountered by firms in interacting with universities, over half cited rules and regulations imposed by universities in relation to confidentiality, intellectual property and the role of technology transfer offices (TTOs). According to firms, such problems had seemingly become twice as common in recent years, perhaps reflecting a policy overemphasis on formal technology transfer and the rise of professionalised TTOs with unrealistic expectations about the economic value of research. Although the business sector itself is the most frequently used source of knowledge, this knowledge is hardly ever used in isolation, with most firms also drawing upon various intermediary bodies as well as the science base. Rather worryingly, UK businesses are less likely than their US counterparts to commit the necessary resources required for effective interactions with universities. Alternatively, they may spread their resources too thinly across too many links. This problem is aggravated by the fact that many UK academics feel they lack the time and resources needed to support their interactions with business. Other problems they experience include inadequate incentives and rewards for such interactions (career progression is still linked primarily to research publications rather than pathway engagement), and bureaucracy or inflexibility on the part of university administrators.

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<sup>42</sup> The respective levels of analysis and the strengths and weaknesses of the different types of study are summarised in tabular form in Annex 2.

Although capturing only a certain part of ‘impact’, it is significant that data from surveys show significant increases in the numbers of patents applied for and granted to UK universities, and to the numbers of spin-offs established, including those surviving three or more years. With regard to spin-offs, the impacts are extremely skewed towards just a handful of highly successful cases. It is also significant that the great majority of the most successful spin-outs had their origins in basic rather than applied research. The research investment per university spin-off in the UK appears to be less than half the equivalent figure in the US. The income from different external pathways to impact more than tripled in real terms between 2001 and 2010, showing that external users have become more willing to pay for access to university research. Most important of the pathways were contract research and collaborative research, followed by continuing professional development and continuing education. Intellectual property was the least important source of income, accounting for just 2-3% of income.

One of the most important pathways to impact is through the movement of people. This has been recognised in long-running support in the UK for the Knowledge Transfer Partnership (KTP – formerly the Teaching Company Scheme). This scheme has led to substantial benefits, both ‘bottom line’ benefits in the form of improved sales, employment or profitability, but also ‘softer’ benefits in the form of enhanced skills and knowledge and embedding capacity in the partner firms. The KTP scheme confirms that an important pathway to impact is through the movement of people, with the evidence suggesting that the contribution of UK universities through this particular route is significant, with an estimated return on investment of some £5 net additional gross value added for every £1 invested. Likewise, funding for knowledge exchange and the promotion of impact through the Higher Education Innovation Fund (HEIF) is estimated to have yielded a gross additional impact factor of nearly 5, along with a large range of other non-quantifiable impacts.

From the literature on the role of research and development and of technological innovation in economic growth and productivity, there is evidence that the responsiveness of economic productivity to public sector research is positive and significantly higher than the response to private sector research, apparently reflecting the fact that publicly research is more concerned with basic research and hence is associated with a higher degree of spillovers in the rest of the economy than private R&D. Moreover, the responsiveness of total-factor productivity to public sector research is higher when business R&D intensity in the economy is higher, emphasising the complementarity of investment in the business sector noted earlier. Without such investment, the ability to capitalise on opportunities arising from public research will inevitably be limited. In addition, the impact of public sector R&D is positively affected by the proportion accounted for by university research (as opposed

to public sector laboratory research). Furthermore, the higher the share of university research financed by the business sector, the *smaller* is the impact of higher education R&D on productivity growth, perhaps because such research is more oriented towards the applied end and therefore less likely to yield longer-term spillover effects at the level of the economy as a whole.

Recent studies on the nature of the relationship between public and private sector R&D and whether they are complementary or tend to substitute for one another provide further evidence of the positive impact of public sector R&D on private sector R&D. In particular, public research is critical to industrial R&D in a small number of industries but has important effects across a much wider range of sectors. In addition, higher education expenditure on R&D has a positive impact on private sector R&D and on the number of R&D personnel employed in the business sector. This strongly reinforces the hypothesis of complementarity between business and public sector R&D. However, the UK's performance in terms of efficiency in converting public support for R&D into economy-wide performance with regard to innovation and patenting places it only in a mid-level position compared with other advanced nations.

Of the studies focussing on the evaluation of research impact in specific sectors, many of the more recent ones have focused on the economic benefits of biomedical and health research. Evaluations carried out in the US and Australia have claimed to find "exceptional returns" from biomedical research, typically of between three and eightfold. However, a fundamental limitation with such approaches is the problem of attribution. None of the claimed economic benefits identified in such studies flow *solely* from the initial biomedical research – there are numerous other contributing factors. Identifying exactly what proportion of the ultimate economic benefit should be attributed to the earlier biomedical research involves making a number of truly heroic assumptions that are open to challenge. Hence, various alternative and wider ranging approaches have been proposed using the 'payback framework' and other 'bottom-up' tracking techniques to assess impact, and acknowledging the complexity of innovation pathways and the multiple complementary investments required. These, too, find substantial health care benefit attributable to publicly funded research, with a typical rate of return being nearly 40%.

Finally, we have seen how UK Research Councils have also carried out a number of evaluations of individual projects, programmes and research centres. In particular, the ESRC has commissioned assessments of several of its centres. While a few of these have attempted to place an economic value of the impact of the research, most have concluded that this is impossible, not least because of the complex non-linear process through which policy and practice are related. Hence, there are major difficulties in establishing unambiguous links between the activities of a research centre and

specific policy changes, not to mention the difficulties in assessing whether the policy itself yielded net economic benefits. Nevertheless, there are many instances where there is qualitative evidence of specific economic or social research having had a significant impact on a particular policy. Various forms of impact can be distinguished, including instrumental, conceptual and empirical impact. Often, the impact is mediated through organisations such as think-tanks and lobby groups, making the task of ascribing impact to the original research even harder.

Let us end by reiterating four main conclusions to emerge from this review. First, in attempting to assess the impact of publicly funded research, one needs to bear in mind that the exploitation of publicly funded research often depends on private sector capacities and investments, factors outside the control of the publicly funded researchers. Consequently, the task is less about assessing the impact of publicly funded research per se, and more about understanding and managing connections between public and private sector in a *system* of knowledge production and innovation. Second, of the various channels or 'pathways to impact' through which research in the university base may contribute to innovation, some are more amenable to quantitative assessment of impact, others less so. Over-emphasis by policy-makers on the more readily measurable forms of impact may be counterproductive to research impact in the long term. Third, although some studies have attempted to come up with a quantitative measure of economic impact or rate of return, this inevitably involves making a host of questionable assumptions. Fourth, there are now a number of alternative and wider ranging approaches to assessing research impact such as the 'payback framework'. These start from a recognition of the complexity of impact pathways and the multiple complementary investments required, and they, too, find evidence of impressive rates of return for publicly funded research.





## References

- Abreu, M., Grinevich, V., Hughes, A. and Kitson, M. (2009) *Knowledge Exchange Between Academics and the Business Public and Third Sectors*, Centre for Business Research and UK<sup>2</sup>IRC, Cambridge.
- Access Economics (2003) *Exceptional Returns: the value of investing in health R&D in Australia*, Australian Society for Medical Research, Canberra (downloaded on 16 April 2012 from <http://www.asmr.org.au/Except.pdf>).
- Aghion P. and Howitt P. (1995) 'Technical Progress in the Theory of Economic Growth', in Fitoussi, J.-P. (ed.) *Economics in a Changing World: Proceedings of the 10th World Congress of the International Economic Association*, 5: 101-122, London: Macmillan.
- AHRC (2006a) *Career path study of PhD students*, DTZ Final Report, December, Bristol: AHRC.
- AHRC (2006b) *Career path study of professional preparation Master students*, DTZ Final Report, December, Bristol: AHRC.
- AHRC (2007) *Impact Strategy* (downloaded on 11 July 2012 from <http://www.ahrc.ac.uk/About/Policy/Documents/impact%20strategy.pdf>).
- AHRC (2010) *Leading the World: The Economic Impact of UK Arts and Humanities Research*, Swindon: Arts and Humanities Research Council.
- AHRC (2011) *The Impact of AHRC Research 2010/11*, Swindon: Arts and Humanities Research Council.
- Alexander, A. (2009) *RCUK/UUK Review of the Impact of Full Economic Costing on the UK Higher Education Sector: A Report prepared for Research Councils UK and Universities UK by a Panel chaired by Professor Alan Alexander*, RCUK and UUK, April.
- Astbury, B. and Leeuw, F.L. (2010) 'Unpacking black boxes: Mechanisms and theory building in evaluation', *American Journal of Evaluation*, 31(3): 363-381.
- Battelle Technology Partnership Practice (2011) *Economic Impact of the Human Genome Project*.
- BBSRC (2011) *Impact Report 2011: BBSRC delivering impact*, Biotechnology and Biological Sciences Research Council, Swindon.
- BIS (2010) *UK Innovation Survey 2009*, BIS, London.
- Bruneel, J., D'Este, P., Neely, A., Salter, A. (2009) 'The Search for Talent and Technology – Examining the Attitudes of EPSRC Industrial Collaborators Towards Universities', *AIM Research Paper*.

- Buxton, M, Hanney, S, Packwood, T, Roberts, S and Youll, P. (2000) Assessing benefits from Department of Health and National Health Service research and development, *Public Money and Management*, 20: 29–34.
- Buxton, M. and Hanney, S. (1996) How can payback from health services research be assessed? *Journal of Health Services and Research Policy*, 1: 35–43.
- Calvert, J. and Martin, B.R. (2001) *Managing Conceptions of Basic Research?* Background Document for the Workshop on Policy Relevance and Measurement of Basic Research, Oslo 29-30 October 2001, Science Policy Research Unit, University of Sussex, Brighton.
- Canadian Academy of Health Sciences (2009) Making an impact: A preferred framework and indicators to measure returns on investment in health research. Report of the Panel on the Return on Investments in Health Research (downloaded on 16 April 2012 from [http://www.caahs-acss.ca/wp-content/uploads/2011/09/ROI\\_FullReport.pdf](http://www.caahs-acss.ca/wp-content/uploads/2011/09/ROI_FullReport.pdf)).
- CIHE (2010a) *Talent Fishing: What Businesses Want from Postgraduates*. A Report for Department of Business, Innovation and Skills, London: CIHE.
- CIHE (2010b) *Supporting Research Excellence: A global business perspective*, CIHE, London.
- CIHE (2010c) *Absorbing Research: The role of university research in business and market innovation*, London: CIHE.
- Cincera, M., Czarnitzki, D. and Thorwarth, S. (2009) 'Efficiency of public spending in support of R&D activities' *European Economy Economic Papers* No. 376, European Communities, Brussels.
- Coe, D.T. and Helpman, E. (1995) 'International R&D spillovers', *European Economic Review*, 39 (5): 859-887.
- Cohen, W.M. and Levinthal, D.A. (1989) 'Innovation and learning: the two faces of R&D', *Economic Journal*, 99: 569-596.
- Cohen, W.M. and Levinthal, D.A. (1990) 'Absorptive capacity: a new perspective on learning and innovation', *Administrative Science Quarterly*, 35: 128-152.
- Cohen, W.N., Nelson, R.R. and Walsh, J.P. (2002) 'Links and Impacts: The influence of public research on industrial R&D', *Management Science*, 48 (1): 1-23.
- Coryn, C.L.S., Noakes, L.A., Westine, C.D. and Schröder, D.C. (2011) 'A Systematic Review of Theory-Driven Evaluation Practice from 1990-2009', *American Journal of Evaluation*, 32(2): 199-226.
- Cosh, A. and Hughes, A. (2010) 'Never mind the quality feel the width: University – industry links and government financial support for innovation in small high-technology businesses in the UK and the USA', *Journal of Technology Transfer* Special Edition, 35: 66–91, March.

- Cosh, A., Hughes, A. and Lester, R.K. (2006) *UK Plc: Just How Innovative Are We?*, Cambridge-MIT Institute, University of Cambridge and MIT.
- Dasgupta, P. and David, P.A. (1994) 'Toward a new economics of science', *Research Policy*, 23 (5): 487-521, September.
- David, P.A., Hall, B.H. and Toole, A.A. (2000) 'Is Public R&D a Complement or Substitute for Private R&D? – A review of the econometric evidence', *Research Policy*, 29: 497-529.
- De Campos, A.L. and Luiz, A. (2010) 'A study on methodologies for research impact assessment: responses of the UK Research Councils to the Worry Report', *Industry and Higher Education* 24(5): 393-397.
- Denison, E.F. (1967) *Why growth rates differ: Post-war experience in nine western countries*. The Brookings Institution, Washington, DC.
- Dodgson, M., Hughes, A., Foster, J. and Metcalfe, J.S. (2011) 'Systems thinking, market failure, and the development of innovation policy: The case of Australia', *Research Policy*, 40: 1145– 1156.
- Donovan, C. (2011) 'State of the art in assessing research impact: introduction to a special issue', *Research Evaluation*, 20: 175-179.
- DTZ (2010) *Economic Impact of Streptomyces Genetics Research*, BBSRC, April, DTZ, Manchester.
- DTZ (2011) *The Value of PhDs: The impact of doctoral education in research Intensive employers*, Final report, June, Edinburgh: DTZ.
- Ehrlich, E. (2011) *An Economic Engine: NIH Research, Employment, and the Future of the Medical Innovation Sector*.
- Elsevier (2011) *International Comparative Performance of the UK Research Base – 2011: A report prepared for the Department of Business, Innovation and Skills*, TSO, London.
- EPSRC (2011a) *Economic Impact of the Innovative Manufacturing Research Centres: Final Report*, DTZ, Manchester.
- EPSRC (2011b) *Research Performance and Economic Impact Report 2010/11*, Engineering and Physical Sciences Research Council, Swindon.
- ESRC (2011) *Research Performance and Economic Impact Report 2010/11*, Economic and Social Research Council, Swindon.
- Fagerberg, J. (1995) 'Catching up and falling behind in economic development: Convergence or divergence? The impact of technology on "why growth rates differ"' *Journal of Evolutionary Economics*, 9 (5): 269-284.

- Foray, D. and Lissoni, F. (2009) 'University Research and Public-Private Interaction' in Hall, B.H. and Rosenberg, N. (eds) *Handbook of the Economics of Innovation*, North Holland.
- Foster, J. (2010) *Productivity, Creative Destruction and Innovation Policy*. Occasional Paper, Australian Business Foundation, Sydney.
- Frank, C. and Nason, E. (2009) 'Health research: measuring the social, health and economic benefits', *Analysis – Canadian Medical Association Journal*, 180 (5): 528-534.
- Frontier Economics (2009) *Measuring the Impact of ESRC Funding: A report prepared for the Economic and Social Research Council*, May, London.
- Godin, B. (2005) *Measurement and Statistics on Science and Technology: 1920 to the present*. Routledge Studies in the History of Science, Technology and Medicine, Routledge, Abingdon, Oxon.
- Gök, A. and Edler, J. (2010) 'Exploring the use of behavioural additionality', in Manchester Institute for Innovation Research, 'Understanding evaluation of innovation policy in Europe', European Commission, DG Enterprise and Industry, pp. 151-200.
- Grossman, G.M. and Helpman, E. (1991) 'Trade, knowledge spillovers, and growth', *European Economic Review*, 35(2-3): 517-526, April.
- Grossman, G.M and Helpman, E. (1994) 'Endogenous Innovation in the Theory of Growth', *Journal of Economic Perspectives*, 8 (1): 23-44.
- Guellec, D. and Van Pottelsberghe de la Potterie, B. (2004) 'From R&D to Productivity Growth: Do the institutional settings and the source of funds of R&D matter?' *Oxford Bulletin of Economics and Statistics*, 66 (3): 353-378.
- Gulbrandsen, M. and Kyvik, S. (2010) 'Are the concepts basic research, applied research and experimental development still useful? An empirical investigation among Norwegian academics', *Science and Public Policy*, 37 (5) June: 343-353.
- Hanney, S.R., J. Grant, S. Wooding and M.J. Buxton (2004) 'Proposed methods for reviewing the outcomes of health research: the impact of funding by the UK's "Arthritis Research Campaign"', *Health Research Policy and Systems*, 2 (4), doi:10.1186/1478-4505-2-4.
- Haskel, J. and Wallis, G. (2010) *Public Support for Innovation, Intangible Investment and Productivity Growth in the UK Market Sector*, IZA DP Discussion Paper Series No. 4772, February, Imperial College, London. (<http://ideas.repec.org/p/iza/izadps/dp4772.html>).
- Hauser (2010) *The Current and Future Role of Technology and Innovation Centres in the UK* A Report by Dr. Hermann Hauser For Lord Mandelson, Secretary of State, Department for Business Innovation & Skills.

- Health Economics Research Group, Office of Health Economics, RAND Europe (2008) *Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK*. London: UK Evaluation Forum.
- HEFCE (2011a) Decisions on assessing research impact (downloaded in July 2012 from <http://www.ref.ac.uk/pubs/2011-01/>).
- HEFCE (2011b) *Higher Education-Business and Community Interaction Survey 2009-10* September 2011/25, London and Swindon: HEFCE,.
- HM Treasury (2004) *The Green Book: Appraisal and Evaluation in Central Government*. London: TSO.
- HM Treasury (2011) *The Magenta Book: Guidance for Evaluation*, April, London: HM Treasury.
- Hughes, A. (2007) 'University-Industry Links and U.K. Science and Innovation Policy' in Shahid Yusuf and Kaoru Nabeshima (eds) *How Universities Promote Economic Growth* World Bank, Washington, D.C.
- Hughes, A. (2011) 'Open Innovation, the Haldane Principle and the new Production of Knowledge: Science Policy and University Industry Links after the Financial Crisis', *Prometheus*, 29 (4): 411-442.
- Hughes, A. (2012) 'University-Industry Links and Impacts Analysis'. A presentation at the *MRC Economic Impact Workshop*, London, 26<sup>th</sup> Oct 2011 reproduced in the MRC (2012) *Measuring the link between research and economic impact: Report of an MRC Consultation and Workshop*, Medical Research Council, Swindon, pp30-35.
- Hughes, A. and Kitson, M. (2012) 'Pathways to Impact and the Strategic Role of Universities: New Evidence on the Breadth and Depth of University Knowledge Exchange in the UK and the Factors Constraining its Development' *Cambridge Journal of Economics*. 36 (3): 723-750.
- Hughes, A. and Mina, A. (2012) *The UK R&D Landscape*. Reprinted and Revised, March, London and Cambridge: Council for Industry and Higher Education and UK Innovation Research Centre.
- Hughes, A., Kitson, M., Abreu, M., Grinevich, V., Bullock, A. and Milner, I. (2010a) 'Cambridge Centre for Business Research Survey of Knowledge Exchange Activities by UK Academics', *UK Data Archive Study no. 6462*.
- Hughes, A., Kitson, M. and Probert, J. with Bullock, A. and Milner, I. (2011a) *Hidden Connections - Knowledge exchange between the arts and humanities and the private, public and third sectors*, May, AHRC and CBR.
- Hughes, A., Moore, B. and Ulrichsen, T. (2011b) 'Evaluating Innovation Policies: A Case Study of the Impact of Third Stream Funding in the English Higher Education Sector' in Colombo, M.G.,

- Grilli, L., Piscitello, L. and Rossi Lamastra, C. (eds) *Policies for science and innovation: design and evaluation*, Cheltenham: Edward Elgar.
- Hughes, A., Spires, R. and Cox, M. (2002) 'Evaluation of SMART (including SPUR): Final Report and Appendices' *DTI Evaluation Report Series No 3* (<http://www.berr.gov.uk/about/economics-statistics/economics-directorate/page21981.html>).
- Hughes, A., Ulrichsen, T. and Moore, B. (2010b) *Synergies and Trade Offs between Research, Teaching and Knowledge Exchange*, A Report to HEFCE by PACEC and Centre for Business Research, University of Cambridge (<http://www.cbr.cam.ac.uk/pdf/SynergiesFullReport.pdf>).
- INGENIO (2007) *Policy and Practice Impacts of ESRC funded Research: Case study of the ESRC Centre for Business Research*. A Report prepared for the Communications and Information Directorate of the Economic and Social Research Council INGENIO, Science Policy Research Unit, SPRU, Brighton.
- Jeumotte, F. and Pain, N. (2005a) 'From ideas to development: the determinants of R&D and patenting', *OECD Economics Department Working Paper No. 457*, OECD, Paris.
- Jeumotte, F. and Pain, N. (2005b) 'Innovation in the Business Sector', *OECD Economics Department Working Paper No. 459*, OECD, Paris.
- Johnson, S. (2011) *Impact of Social Science on Policy: Sure Start Case Study*. Report to Economic and Social Research Council, Hull University Business School.
- Johnston, S.C., Rootenberg, J.D., Katrak, S., Smith, W.S. and Elkins, J.S. (2006) 'Effect of a US National Institutes of Health programme of clinical trials on public health and costs', *The Lancet*, 367, 1319-1327.
- Kaldor, N. and Mirrlees, J. (1962) 'A New Model of Economic Growth', *Review of Economic Studies*, 29: 174-190.
- Kalucy, L., Jackson Bowers, E. and McIntyre, E. (2007) *Primary Health Care Research Impact Project*. Final Report Stage 1 (downloaded on 16 April 2012 from [http://www.phcris.org.au/phplib/filedownload.php?file=/elib/lib/downloaded\\_files/publications/pdfs/phcris\\_pub\\_3338.pdf](http://www.phcris.org.au/phplib/filedownload.php?file=/elib/lib/downloaded_files/publications/pdfs/phcris_pub_3338.pdf)).
- Kellogg, W.K., Foundation (2004) *Logic Model Development Guide*, Battle Creek, Michigan: W.K. Kellogg Foundation.
- Kwan, P., Johnston, J., Fung, A.Y.K., Chong, D.S.Y., Collins, R.A. and Lo, S.V. (2007) A systematic evaluation of payback of publicly funded health and health services research in Hong Kong (downloaded in May 2012 from [www.ncbi.nlm.nih.gov/pmc/articles/PMC1952059/](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1952059/)).

- Lasker Foundation (2000) *Exceptional Returns: the Economic Value of America's Investment in Medical Research*, Mary Woodard Lasker Charitable Trust, New York (downloaded in April 2012 from <http://www.laskerfoundation.org/media/pdf/exceptional.pdf>).
- Laursen, K. & Salter, A., (2006) 'Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms', *Strategic Management Journal*, 27: 131-150.
- Levitt, R., Celia, C., Diepeveen, S., Chonai, S.N., Rabinovich, L. and Tiessen, J. (2010) *Assessing the impact of arts and humanities research at the University of Cambridge: A report prepared for the University of Cambridge and the Arts and Humanities Research Council*, Santa Monica, CA: RAND Europe.
- Library House (2007) *Spinning Out Quality: University spin out companies in the UK* February Library House, Cambridge.
- Lichtenberg, F.R. (1993) 'R&D Investment and International Productivity Differences', *NBER Working Papers 4161*, Washington: National Bureau of Economic Research.
- Lucas, R. (1988) 'On the Mechanics of Economic Development', *Journal of Monetary Economics*, 22 (1): 3-42.
- Martin, B.R. (2012) 'Are universities and university research under threat? Towards an evolutionary model of university speciation' *Cambridge Journal of Economics Special Issue*, 36 (3): 543-565.
- Martin, B.R. and Tang, P. (2006) *The Economic and Social Benefits of Publicly Funded Basic Research*, Report to the Office of Science and Innovation, Department of Trade and Industry, Brighton: SPRU, University of Sussex.
- Martin, B.R., Salter, A., Hicks, D., Pavitt, K., Senker, J., Sharp, M. and von Tunzelmann, N. (1996) *The Relationship Between Publicly Funded Basic Research and Economic Performance: A SPRU Review*, London: HM Treasury.
- Metcalfe, J.S. (2010) 'University and Business Relations: Connecting the Knowledge Economy', *Minerva* 48: 5-33.
- Metcalfe, S. (1995) 'The economic foundations of technology policy: equilibrium and evolutionary perspectives' in Stoneman, P. (ed.) *Handbook of the Economics of Innovation and Technological Change*. Oxford: Blackwell Publishers.
- Mina, A., Connell, D. and Hughes, A. (2009) 'Models of Technology Development in Intermediate Research Organisations', Centre for Business Research Working Paper Series. WP 396, December.
- MRC (2011) *The Medical Research Council Economic Impact Report 2010-11*, Swindon: Medical Research Council.

- Murphy, K. and R. Topel (2003) 'Diminishing returns? The costs and benefits of improving health', *Perspectives in Biology and Medicine*, 46 (3 supplement): S108–S128.
- Murphy, K.M. (ed.) (2003) *Measuring the Gains from Medical Research: An Economic Approach*, Chicago: University of Chicago Press.
- Nason, E., Janta, B., Hastings, G., Hanney, S., O'Driscoll, M. and Wooding, S. (2008) *Health Research – Making an Impact. The Economic and Social Benefits of HRB-Funded Research*, Dublin: RAND Europe and Health Research Board (HRB).
- National Academy of Engineering (2003) *The Impact of Academic Research on Industrial Performance*, National Academies Press, Washington.
- NERC (2006) *Economic benefits of environmental science: A study of the economic impacts of research funded by the National Environment Research Council* Natural Environment Research Council, Swindon. November
- NERC (2011) *NERC Impact Report 2011: Environmental Science for UK Economic Growth and Wellbeing*, Natural Environment Research Council, Swindon.
- OECD (2002) *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*, OECD, Paris.
- OECD (2012) (downloaded on 25 April 2012 from <http://stats.oecd.org/glossary/detail.asp?ID=120>).
- Oxford Economics (2009) *The Economic Impact of Physics Research*, Oxford Economics, Oxford.
- Oxford Economics (2010) *The Economic Benefits of Chemistry Research to the UK* Final Report, September, Oxford Economics, Oxford (downloaded from [www.oxfordeconomics.com/samples/chemistry.pdf](http://www.oxfordeconomics.com/samples/chemistry.pdf)).
- PA Consulting Group and SQW Consulting (2007) *Research Councils UK: Study on the economic impact of the Research Councils* (in three parts) Part I: Summary; Part II: Case Studies; Part III: Appendices, including supporting analyses for case studies. September-October, Town??.
- PACEC (2001) 'Evaluation of Smart' (including SPUR): Final Report and Appendices, *DTI Evaluation Report Series* No. 3, September, London: DTI.
- PACEC (2011) *Evaluation of the Collaborative Research and Development Programmes*: Final report to the Technology Strategy Board, Cambridge and London: PACEC.
- PACEC/CBR (2009) *Evaluation of the effectiveness and role of HEFCE/OSI third stream funding* Report to HEFCE by PACEC and the Centre for Business Research, University of Cambridge April 2009/15 HEFCE London and Swindon.
- Pollitt, A., Wooding, S., Hanney, S., Buxton, M, and Grant, J. (2011) *Project Retrosight. Understanding the returns from cardiovascular and stroke research*.



- PPG (2007) *The policy and practice impacts of the ESRC's "responsive mode" research grants in politics and international studies: Report to the Economic and Social Research Council*, PPG, LSE Public Policy Group, London School of Economics, London.
- PricewaterhouseCoopers (2008) *Economic and Social Research Council Innovation Centres Impact Case Study –Final report*, PricewaterhouseCoopers, London
- Raftery, J., Hanney, S., Green, C., Buxton, M. (2009) 'Assessing the impact of England's National Health Service R&D Health Technology Assessment program using the "payback" approach', *International Journal of Technology Assessment in Healthcare*, 25 (1): 1-5.
- RAND (2007) *Policy and Practice Impacts of Research Funded by Economic and Social Research Council: A Case Study of the Future of Work Programme*, RAND Europe Technical Report, Cambridge.
- RCUK (2011) *Research Council's UK Impact Report 2011*, Swindon: Research Councils UK.
- Regeneris Consulting (2010) *Knowledge Transfer Partnerships Strategic Review – A report by Regeneris Consulting for the Technology Strategy Board*, February, Altrincham, Cheshire: Regeneris Consulting Limited.
- Research Council Economic Impact Group (2006) (*"The Worry Report"*), *Increasing the Economic Impact of Research Councils: Advice to the Director General of Science and Innovation*, DTI, London, July, ref. 06/1678.
- Romer, PM (1986) Increasing returns and long-run growth, *Journal of Political Economy*, 94, 1002-1037.
- Romer, PM (1990) Endogenous technological change, *Journal of Political Economy*, 98 (5, part 2): S71-102.
- Romer, P.M. (1994) 'The Origins of Endogenous Growth', *Journal of Economic Perspectives*, 8 (1): 3-22.
- Rosenberg, L.E. (2002) Exceptional economic returns on investments in medical research, *Medical Journal of Australia*, 177, 368-371.
- Russell Group (2010) *The Economic Impact of Research conducted in Russell Group Universities*, London, Russell Group.
- Salter, A., D'Este, P., Martin, B., Geuna, A., Scott, A., Pavitt, K., Patel, P. and Nightingale, P. (2000) *Talent, not Technology: Publicly Funded Research and Innovation in the UK*, Committee of Vice-Chancellors and Principals (CVCP), London.
- Salter, A.J. and Martin, B.R. (2001) 'The economic benefits of publicly funded basic research: A critical review', *Research Policy*, 30: 509-532.

- Salter, A., Tartari, V., D'Este, P. and Neely, A. (2010) *The Republic of Engagement: Exploring UK academic attitudes to collaborating with industry and entrepreneurship*, AIM and UK~IRC, London and Cambridge.
- Scherer, F.M. (1999) *New Perspectives on Economic Growth and Technological Innovation* Brookings Institution, Washington D.C.
- Scott, A., Steyn, G., Geuna, A., Brusoni, S. and Steinmueller, E. (2002) *The Economic Returns to Basic Research and the Benefits of University-Industry Relationships: A Literature Review and Update of Findings*, report for the Office of Science and Technology, Brighton: SPRU - Science and Technology Policy Research.
- Segal Quince Wicksteed (2002) 'Evaluation of Teaching Companies Scheme: Final Report to the Small Business Service', DTI Evaluation Report Series No. 7, Segal, September, London: DTI.
- Silverstein, S.C., Garrison, H.H. and Heinig, S.J. (1995) A few basic economic facts about research in the medical and related life sciences, *FASEB Journal*, 9: 833-840.
- Smith, K. (2000) Innovation as a Systemic phenomenon: Rethinking the role of Policy, *Enterprise & Innovation Management Studies*, 1 (1): 73-102.
- Solow, R (1957) Technical change and the aggregate production function, *Review of Economics and Statistics*, 39: 312-20.
- STFC (2009) *New Light on Science: The Social and Economic Impact of the Daresbury Synchrotron Radiation Source, (1981-2008)*, Science and Technology Facilities Council, Swindon.
- STFC (2011) *STFC Impact Report 2011*, Science and Technology Facilities Council, Swindon.
- Stokes, D. (1997) *Pasteur's Quadrant. Basic Science and Technological Innovation*, Washington: Brookings Institution Press.
- Umbach, T (2011) *The economic benefits of publicly funded medical research Conducted by AAMC-Member Medical Schools and Teaching Hospitals*, Washington: Association of American Medical Colleges.
- Wakeham, W. (2010) *Financial Stability and Efficiency in Full Economic Costing of Research in UK Higher Education Institutions: Report of RCUK/UUK Task Group chaired by Sir William Wakeham*, UUK and RCUK, June.
- Wooding, S., Hanney, S., Pollitt, A., Buxton, N. and Grant, J. (2011) *Project Retrosight: Understanding the returns from cardiovascular and stroke research, The Policy Report*, Santa Monica and Cambridge: Rand Corporation.
- Wooding, S., Nason, E., Thompson-Starkey, T.G., Hanney, S. and Grant, J. (2009) *Mapping the impact. Exploring the payback of arthritis research*, Cambridge, RAND Europe and ARC.

## **Annex 1     Market failure, systems failure and the rationale for government support for R&D**

### **1. Market Failure**

The essential idea behind market failure justifications for public intervention is that if markets worked perfectly, intervention would be unnecessary. Perfection is achieved in a state of affairs which requires that all costs and benefits are fully reflected in market prices, and that consumers and producers have no monopoly or other powers to distort markets. Moreover, they are perfectly informed not only about current production and consumption possibilities but all future possible contingencies so that account can be taken of all possible future alternative scenarios. All costs and benefits should therefore be reflected in market prices. There are thus, for example, no ‘spillovers’ into the rest of society, where spillovers are costs and benefits for others that arise from private actions which are not fully reflected in market prices. Spillovers arise, for example, when some users can get access to a good without paying a price to the producer. This is termed ‘non-excludability’. In addition, no price should be charged for additional consumption of a good if that consumption does not preclude anyone else from consuming it. This is termed ‘non-rivalry’ in consumption. Policy is justified when a market failure can be identified relative to the perfect state and will be aimed at ‘correcting’ these market failures. Thus the absence of futures markets to price for all future possible outcomes combined with a desire to avoid risk can lead to under-investment in R&D compared with less uncertain investment activities. Knowledge is also characterised by non-rivalry. Once produced, products such as drugs may be copied. Knowledge is also characterised by non-excludability since, once created, access to the knowledge should be costless because its use by one agent does not inhibit that by others. The answer to these market failures, which would lead to underproduction of knowledge, is create legal rights to charge for access or to subsidise knowledge production in the private sector, or to produce it in the public sector and to grant free access.

A conceptual problem with the market failure approach in relation to innovation and research policy is that market failures arising from extreme uncertainty and the absence of complete futures markets to deal with it, the presence of incomplete and unevenly distributed information, and information spillovers are endemic to research and innovation. They are naturally occurring features of the research and innovation process.

They are therefore

“an intrinsic consequence of the process of innovation itself and could only be eliminated if innovation ceased. Thus the model of perfect competition in a stationary state, a world in which

innovation, or indeed any change of human knowing is absent, can serve only as a distorting mirror in which to reflect the innovation policy problem ...” On the contrary, “... a knowledge driven economy cannot be stationary ... competition is therefore a process of disequilibrium dynamics not a state of equilibrium affairs” (Dodgson et al., 2011, p.1146).

## 2. Systems Failure

An alternative evolutionary systems approach emphasises the inherent uncertainties of the research and innovation process. It focuses on more general ‘systems failures’ and inhibitions to evolutionary change in addition to pervasive uncertainty and spillover effects. These arise, in particular, in relation to problems of co-ordination or the connection between innovation system elements such as firms, universities and other organisations. This co-ordination extends beyond markets alone to encompass a wide range of collaborative and network pathways. Systems failures include ‘institutional’ failure arising from conflicting motivations norms and standards of behaviour such as those between the academic and business spheres; and lock-in failures arising from path-dependent investment decisions which limit business adaptability and adjustment because of past investments. Public support for R&D may therefore be focused on ensuring complementary public and private investments through support for collaborative non-market activities or public interventions to redirect or give impetus to new technologically transformations where existing private sector investments and capabilities are tied to an older set of technologies (see for example Smith, 2000; Foster, 2010; Metcalfe, 1995; Dodgson et al., 2011).

In view of the emphasis in innovation policy discussions on ‘systems’ thinking it is appropriate to adopt this wider perspective in relation to analysing the impact of public sector funded research.

## Annex 2 Summary of Different Approaches to Assessing Impact

### Exhibit A2.1 Summary of Different Approaches to Assessing Impact

Study	Level/unit of assessment	Method	Approach	Estimated impact	Strengths	Limitations
Elsevier	Micro -publication/ individual researcher	Bibliometric	Cross-sector knowledge flows and movement of authors	40% of corporate downloads are academic articles; thousands of authors move across sectors	Very large database; 'objective'	Focuses on output (and producers and users of output) rather than impact
Surveys of academics	Micro - individual researcher/ project	Survey	Ask UK researchers e.g. EPSRC PIs re pathways	Academics use wide range of pathways – increasing over time; many more involved in 'soft' rather than 'hard' commercialisation	Captures full range of impact channels	No direct measure of impact
Surveys of firms	Micro - projects	Survey	Ask firms re pathways and impact	Heavy involvement in several pathways	Users' own direct assessment of impact	Self-selected group (e.g. firms collaborating with EPSRC)
Impact metrics	Meso - universities	Survey data and case-studies	Data on spin-outs, IP, consultancy, contract research etc.	Several billion pounds from licensing and value of spin-out companies; impact highly skewed	Provides quantitative data on impact	Aggregate meso-level data- difficult to link impacts with inputs
Assessment of KTP	Micro - projects	Survey	Ask partner firms	'Soft' forms of knowledge exchange very important, especially for SMEs; £4billions of new sales; impact highly skewed;	Provides quantitative data on impact	Specific scheme related group
Assessment of TSB	Micro - collaborative projects	Survey	Ask collaborating firms	~£3 billion of net added gross value; 13,000 new jobs; each £1 of grant generates gross value added of £6.7; impact highly skewed;	Provides quantitative data on impact	Specific scheme related group
Assessment of HEIF	Meso - universities	Survey; case studies & interviews	Economic analysis of inputs, outputs and impact	Generated £3-4 billion in gross additional income; rate of return of 5 or more. Impact highly skewed	Provides quantitative data on impact	Difficult counterfactual; multiple comparisons used for robustness
Economy-level studies	Macro - economies	Macro-economic analysis	Economic analysis of relationship of public sector research to economic output and productivity growth	Rate of return from public R&D > that from private; RC-funded research => substantial spillovers;	Supposedly rigorous and objective	Complex chain of causality; arbitrary assumptions re relative influence of different factors
Relationship between public and private R&D	Macro - public and private sectors	Innovation surveys; R&D data and other economic data	Economic analysis of public and private R&D funding, and of innovation performance	Public R&D has positive impact on private R&D and on patenting	Supposedly rigorous and objective	Complex chain of causality; arbitrary assumptions re relative influence of different factors
Evaluations of biomedical research	Meso - fields/ programmes	R&D data and other economic data	Economic analysis	"Exceptional returns"; rates of return ranging from 3:1 to 14:1	Supposedly rigorous and objective	Complex chain of causality; arbitrary assumptions re relative influence of different factors
HERG/RAND	Meso - programmes	'Payback framework'	Broader economic analysis of benefits from medical research programmes	Benefits long term but substantial (e.g. £1 investment => £0.39 p.a.)	Probably more wide ranging and rigorous than other evaluation analyses	But still suffer from similar problems e.g. re relative influence of different factors
Research Council evaluations	Meso - programmes/ centres	Case studies and other data	Qualitative and quantitative approaches	Strong qualitative evidence of impact and range of quantitative impact metrics	Some of these studies reasonably rigorous, others less so	Still suffer from similar problems e.g. re relative influence of different factors

Source: compiled by the authors.

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

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

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

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

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- Ensure that new research on innovation in both the public and private sectors has the greatest effect on policy and practice.
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