Prometheus
Vol. 29, No. 4, December 2011, 411–442

RESEARCH PAPER

Open innovation, the Haldane principle and the new production of knowledge: science policy and university–industry links in the UK after the financial crisis

Alan Hughes*

Centre for Business Research and UK Innovation Research Centre, University of Cambridge, UK

The paper looks at the system of knowledge production and innovation in the UK from a Mode 2 perspective. It is critical of policy that focuses on science and engineering, on distinctions between basic and applied research, and that looks to notions of the entrepreneurial university. Extensive survey work of individual academics and UK firms reveals an extensive range of linkages between academics and industry, many personal rather than institutional. Formal mechanisms to link the university with the firm are rarely key initiators of connections. As key policy challenge is to design institutions and incentives that enhance the reflexive interplay between universities and external organisations and which build on the full range of interactions and disciplines.

Introduction

In the UK, as elsewhere in OECD economies, it has become commonplace in innovation and science policies to stress the role that universities can play in increasing economic welfare. The world financial crisis and recession of 2008/9 has served to reinforce this role as universities and innovation are attributed a pivotal role ensuring competitive recovery and economic restructuring in the anticipated upturn. Thus enhanced science budgets have played a prominent part in the rhetoric accompanying stimulus packages in the US, Europe, Australia and elsewhere. These events in the UK have resurrected old debates about the implications for the nature of university knowledge production of attempts to link explicitly accountability, assessment and funding of university research to its economic and social impact. They have also been accompanied by an expansion of conceptual and empirical research into the role that universities play in the innovation process and appropriate policy design to enhance this role.

This paper is designed to review some of these developments in the specific context of the UK. In doing so, it uses new large-scale survey evidence on academic and business views of the nature and role of university–industry links in the UK. The presentation of this evidence is set against a brief review of the current and past debate over these issues in the UK. It is also set in the context of approaches to the analysis of them which have stressed the emergence of

*Email: a.hughes@cbr.cam.ac.uk

ISSN 0810-9028 print/ISSN 1470-1030 online

http://dx.doi.org/10.1080/08109028.2011.639565
http://www.tandfonline.com

new distributed and complex modes of knowledge production (Gibbons *et al.*, 1994); the emergence of 'entrepreneurial' university structures as part of a 'triple helix' of university/industry/public sector form and function (Etzkowitz *et al.*, 2000); the increased openness of commercial sector innovation business models (Chesbrough, 2003); and the increasing attention paid to universities as actors in 'systems of innovation' identified at national, sectoral or regional level (Mowery and Sampat, 2005). Within this role, the paper argues for the use of the notion of universities as 'public spaces' within which important reflexive interactions, between other actors on the system of knowledge production and innovation, and between them and universities, can be fostered. The paper concludes by arguing that the role of universities in innovation is important, but is misunderstood in much policy rhetoric. University–industry links are much less frequently and less highly valued by businesses than other sources of knowledge for innovation. Customers, suppliers and other intermediary agencies and institutions dominate. Policy discussion has often placed too much weight on the notion of an 'entrepreneurial university' model which emphasises new business spin-offs and licensing, and their emergence from disciplines within science, technology, engineering and mathematics (STEM). The nuanced but distinctive role that universities play spans a wide range of people-based and problem-solving activities. These are most frequently developed and mediated through informal softer relationships which permit a reflexive relationship between so-called basic and applied research. Developing effective Mode 2 relationships in the UK and the capacity to exploit the opportunities of increasingly open models of business innovation poses a major policy challenge. It requires structures of funding and organisational forms which enhance the 'public space' roles of universities. This will encourage a reflexive interplay between the commercial and university sectors help avoid a simplistic distinction between applied and basic research in key resource allocation decisions.

The current policy conjuncture in the UK

In the UK, during the course of 2008 and 2009, a series of policy announcements and speeches by ministers at the then Department of Innovation, Universities and Skills stressed the importance of universities in the development of innovative strategies to recover from the recession. In doing so, the need for a strategic allocation of research resources was emphasised, in terms of both the restructuring of the economy in the aftermath of the collapse of financial services and of the perceived need to redevelop strengths in manufacturing activities. This was contemporaneous with a renewed emphasis on identifying and measuring the effect of publicly-funded research and changes which required applicants to the UK research councils to provide an indication of the wider 'impact' of their proposed research. More short-term skills-focused aspects and local demand-focused aspects of the role that universities might play were reflected in the launch of schemes to encourage universities to develop internship programmes with employers and local business community-focused training, retraining and skills development courses (Denham, 2008, 2009a, 2009b, 2009c; HEFCE, 2008; NESTA, 2008; DIUS, 2009a, 2009b; Drayson, 2009; Kitson *et al.*, 2009). These developments were accompanied by an avowed return to an increased degree of selectivity in the way in which overall government policy towards industry would be developed (Mandelson, 2008), and an emphasis on increased selectivity and interdisciplinarity in funding research.

The requirement that future applicants for research council funding would have to write a two-page summary of the expected impact of their research led to a minor revolt by a number of scientists, including fellows of the Royal Society and Nobel laureates, protesting that this was a bridge too far in the pursuit of enhanced links between the nature of scientific research and commercial and other applications (Nurse, 2009; Corbyn, 2009a, 2009b, 2009c; Times Higher Education 2009a, 2009b, 2009c). This was the resurrection of a long-standing debate about the relative roles of government and the science base in the identification of strategic areas for research and the allocation of resources between competing claimants on that research. Pathways to Impact and Impact Evaluation are now firmly embedded in both Research Council processes and the Research Excellence Framework exercise in the UK (HEFCE, 2010; Research Councils UK, 2011).

In presenting the main outlines of the government's future commitment to the support of research in 2008, the then Secretary of State for Innovation, Universities and Skills, John Denham, was at pains to point out the government's commitment to a long-standing principle of research funding allocation. This is the so-called 'Haldane principle', dating from the beginning of the last century.[1] In a speech to the Royal Academy of Engineering in London in April 2008, he stated that 'For many years, the British government has been guided by the Haldane Principle – detailed decisions on how research money is spent are for the science community to make through the research councils'. The principle was restated in the publication announcing the financial settlement for science funding by the new UK coalition government in 2011, which reiterated that 'The Haldane Principle means that decisions on individual research proposals are best taken by researchers themselves through peer review and that prioritization of an individual Research Council's spending within its allocation is not a decision for Ministers' (BIS, 2010, p.57), although the overall science budget, broad allocations between councils and identifying national priorities were stated to be so.

The need to restate this principle reflected the long-standing objective of the scientific and academic community to maintain control of the process of identifying and pursuing topics of research. The objective has been challenged by successive governments, striving to allocate research funding in pursuit of 'impact' and the commercialisation of science. At the heart of this conflict are claimed differences between the motivations for, and purpose of, research by groups and individuals based in the university sector and the research needs of government and the industrial and commercial sector. These differences were highlighted in the process to determine resource allocation for science and research funding in the UK in the period 2008–11, and in the contemporaneous debate over student fees and university funding (Browne, 2010; BIS, 2011). The need to challenge an apparent aspiration by government to direct research towards commercialisation needs and prioritise impact and, at the same time, to demonstrate how significant impact already was, led to an explosion of reports and policy publications (e.g. British Academy, 2008, 2010; Royal Society, 2010; Council for Science and Technology, 2010; Universities UK, 2010; Bate, 2011). In the event, research funding for current (but not capital) expenditures has been protected in money terms, but will suffer a fall in real terms over the period 2011/12 to 2014/15 (BIS, 2010).

The need to reassert differences and a separation between the research endeavour in the private and public sectors can also be understood in terms of resistance to a wider set of forces leading to convergence between industry and university research. This has been emphasised in a number of influential analyses of the changing nature of knowledge production and business innovation. Two important lines of arguments may be mentioned here. The first of these is the Mode 2 model of knowledge production (Gibbons *et al.*, 1994) and the related triple helix model of university–industry links (Etzkowitz *et al.*, 2000). The second is the development of 'open' models of innovation in the commercial sectors (Chesbrough, 2003).

The Mode 2 model stresses first that knowledge is generated in the context of specific applications, and challenges the view that knowledge can be considered as being transferred from pure or basic contexts into applications. Second, the process of knowledge production is seen as embodied in the capabilities and expertise of research teams (and the individuals of which they consist) rather than as embodied in codified outputs, such as published papers or patent applications for onward transmission. Thirdly, and most apposite in relation to the discussion of university–industry interactions, is the notion that knowledge is produced in a much wider range of locations than in the conventional university sector. In particular, the use of information technologies is seen as leading to the creation of new forms of organisations which can 'join the research game' (Nowotny *et al.*, 2001, 2003). Mode 2 knowledge production is also seen as highly reflexive in the sense that the environment in which problem-solving occurs influences both the choices of topics to be investigated and the methodologies to be employed, as well as potential end uses. This, in turn, is related to changes in the nature of accountability for those involved in knowledge production. The idea that there are objectively determined problems manifested in the natural or social world which can be identified as worthy of investigation independent of the context of the research and purpose and motivation of the researchers themselves is challenged. This makes it difficult to rely on conventional forms of 'independent' quality control in terms, for example, of scientific peer review. The result is that 'we must learn to live with multiple definitions of quality, a fact that seriously complicates (even compromises) the processes of discrimination, prioritization, and selectivity upon which policy makers and funding agencies have come to rely' (Nowotny *et al.*, 2003, p.188).

The emergence of the new model of knowledge production has been associated with a number of underlying contextual forces. The first of these is the increasing policy emphasis on the commercialisation of research (and the implications this might have for scientific autonomy). The second is the growth of mass higher education, expanding the potential for highly qualified individuals outside the university sector to contribute to and direct research activity. Third is the increased globalisation of knowledge and the integration and distribution of knowledge driven by the growth of information technology as a dissemination and integration mode. Finally, the humanities (normally considered the most detached set of disciplines in terms of links to commercialisation and application) were in fact becoming a central contextual force driving the new production of knowledge. Nowotny *et al.* (2003) leave as open questions the implications of these developments for the ways in which institutions might change, both in terms of their role in the production of knowledge, and in terms of the way in which Mode 2 knowledge production would be effectively managed in different organisational settings.

This Mode 2 model is contrasted with a Mode 1 model which it does not replace but runs alongside. In Mode 1, pure experimental or theoretical activity is seen as hierarchically privileged. The identification and pursuit of new knowledge is driven by the investigation of 'objective' natural and social world phenomena. The quality of this research endeavour is linked to the autonomy of universities; the freedom of scientists (whose activities the universities house) to identify and prioritise the objectives of research; the maintaining of disciplinary boundaries, which are privileged against interdisciplinary activities; and a model of scientific accountability which is driven by internally-refereed peer review.

The idea of organisational transposition and change embedded in the Mode 2 approach is closely related to the triple helix model of entrepreneurial university activities (Etzkowitz *et al*., 2000). While challenging the notion that there is an historical shift beginning with Mode 1 and progressing to Mode 2, the triple helix account of knowledge production asserts that there is a convergence in the roles that universities, the government and industrial organisations play (Etzkowitz and Leyersdorff, 2000). In the triple helix model, universities increasingly take on industrial roles at the same time as public sector and industrial organisations take on academic roles. For universities, this is seen in particular as a transformational experience at the end of a long road in which a number of changes have occurred:

> ... the universities' assumption of an entrepreneurial role is the latest step in the evolution of a medieval institution from its original purpose of conservation of knowledge to the extension and capitalisation of knowledge. As the university increasingly provides the basis for economic development through the generation of social and intellectual, as well as human, capital, it becomes a core institution in society. (Etzkowitz, 2002, p.1)

This particular view of the way in which Mode 2 forces may work out is strongly influenced by the experience of the Massachusetts Institute of Technology. The model itself, however, is in principle not so deterministic as that example might suggest (see, for example, Cosh and Hughes, 2010).

More recently, another line of argument has been developed which may be seen as relating to the same contextual background which the Mode 2 authors saw driving the changing production of knowledge. This line of argument has as its focus the changing nature of the commercial innovation process. It focuses, in particular, on the internal business processes of the private sector. It emphasises the development of business models which drive private sector organisations to externalise the sources of knowledge on which they draw for their innovation. At the same time, they are also driven to develop mechanisms for the exploitation of internally generated ideas through a variety of means, such as spin-outs, licensing and the generation of new businesses (Chesbrough, 2003).

This literature draws on many of the same underlying contextual factors as the Mode 2 literature to explain why open innovation is emerging as a new successful business model. In the introduction to his seminal book on this topic, Chesbrough, in the same vein as Gibbons *et al*. (1994), argues that changes in innovation practice should be seen in terms of a tale of two models or paradigms. In the closed innovation paradigm, as in Mode 1, there is essentially a linear conception of the move from research projects through to the market. The management of innovation consists of the attraction of the brightest people to work inside the organisation to discover new products, processes and services, and to get to the market first. There is tight control of intellectual property and heavy investment in research and development in the internal generation of new ideas for exploitation. This model is seen as breaking down because of increased mobility of highly experienced and capable scientists who take with them a great deal of human capital. The growth of mass education is also seen as leading to a spillover of human capital movement from the central laboratories of corporations to all sorts of other enterprises which, coupled with the growth of private sector venture capital, leads to the creation of new, smaller businesses. Finally, the growth of knowledge in competitors, customers and suppliers leads to rapid erosion of advantages built purely on internal investment. The result is a move to what is termed an 'open innovation paradigm'. A much wider range of knowledge sources and investments for ideas is used, both external and internal to the firm, and a much wider variety of exploitation mechanisms, including the formation of new businesses, is developed. While this approach focuses on the interrelationship between businesses, it also has clear implications for the extent to which the search for relevant knowledge inputs includes the pursuit of relationships with universities. There is a wider search for talent and knowledge and hence a greater demand pull for knowledge from the 'science base'.

These Mode 2 and open innovation conceptual approaches have generated a rich and controversial subsequent literature (see Hessels and van Lente, 2008). In this paper, we analyse the extent to which this descriptive heuristic is reflected in the UK pattern of knowledge production and particularly in the nature of university–industry interactions. In view of the debate about the extent to which the production of knowledge has changed over time, and with it the role of universities and scientific autonomy, the next section provides a brief historical overview of perceived past patterns and weaknesses in the UK. The paper then provides a concise overview of the current involvement of academics and the business community in knowledge production and exchange based on two recent surveys of the UK academic and business communities (Hughes *et al.*, 2010a, 2010b).[2]

Commercialisation of science: retrospect

Concern in the UK with weaknesses in the links between research carried out in universities and its commercialisation is long-standing. It has been consistently linked to perceptions of weak comparative international growth and productivity performance.[3] In 1920, Alfred Marshall referred to contemporary studies which showed that there were:

> ... numerous cases in which members of the small band of British scientific men have made revolutionary discoveries in science; but yet the chief fruits of their work have been reaped by businesses in Germany and other countries, where industry and science have been in close touch with one another. (Marshall, 1920, p.101, footnote 1)

It is interesting to note, however, that Marshall went on to argue that it was important to distinguish between different classes of scientific research and that in the period leading up to his analysis a number of substantive changes had occurred in the organisation of research and industry which led him to conclude that:

> ... it is now generally recognised that national industry requires three distinct classes of laboratories. The first seeks the extension of knowledge at large: the second aims at knowledge in regard to special requirements of a particular branch of industry: the third checks the quality of the output of individual works.... History shows that almost every scientific discovery, which has ultimately revolutionised methods of industry, has been made in the pursuit of knowledge for its own sake, without direct aim at the attainment of any particular practical advantage: universities are the proper places for such pursuit of 'pure science' and for the establishment of laboratories, etc., devoted to it. But though the eagerness of an academic student should increase with every prospect in establishing a new truth, independently of any practical gain which it may promise; yet his studies will lose nothing, and the world may gain much, from his keeping in touch with some of those industries, whose methods might be improved by increasing knowledge of the properties of the products which he is studying. Therefore it is well that laboratories devoted to the advance of pure science should take some account to the work of a second class of laboratories, whose researchers are specialised on the attainment of particular practical ends. (Marshall, 1920, pp.99–100)

Marshall then went on to argue that the latter may consist of two main kinds of laboratory structures, depending on the scale of business in the industry in question. For sectors dominated by large-scale businesses, he foresaw the development of large-scale laboratories, while in the case of industries characterised by relatively small-scale businesses, the development of industry-based and co-funded laboratories would emerge. Finally, he opined that these technical research laboratories, whether single-owned or association-based, could help what he identified as a third class of laboratories whose chief work was:

> ... mechanical rather than chemical. Such a laboratory does not as a rule do any considerable research work: but it enables the business, to which it is attached, to make sure that each of its products from day to day, or even from hour to hour, is chemically or mechanically true to its proper standing. (Marshall, 1920, p.101)

In his comparisons of the economic performance of Germany, France, the UK and the US, it was to Germany that Marshall attributed a particularly significant role for the link between science and industrial performance. His chapter on Germany is strikingly entitled 'The industrial leadership of Germany: science in the service of industry'. Marshall's account emphasises that the role of science has to be seen alongside many other factors influencing the nature of German industrial performance, including the impact of the establishment of the Zollverein and of the railway system (including the impact of the latter on the free exchange of ideas and personnel between universities). It is striking that he emphasises both the quality of the mass education system raising average skill levels and technical competence in the German labour force, as well as the development of basic science and its link to industry in certain selected areas. In particular, he emphasises that German leadership and its closing of the gap with British performance was in industries where academic training and the importance of applied laboratories were particularly important, and that these were growing in relative importance, based on advances in chemistry and in electrical and biological sciences. He related these advances not only to agricultural developments but also to applications, in particular in dyes, optics, materials and related areas. While it had been appreciated that the German economy was making significant advances in these areas, Marshall's chapter on Germany, written before the First World War and not revised in the 1920 edition, predicted industrial superiority in Germany in precisely those areas where the outbreak of war led to immediate shortages of supply for the UK, which had become dependent on imports from Germany in these areas [see, for example, the discussion in Varcoe (1970)].

It is worth recalling Marshall's analysis here because it reflects widespread concern at the state of relations between British science and industry revealed by the German industrial and then military challenge (see, for example, Varcoe, 1970; Edgerton, 2006). Moreover, this concern led to a number of important developments which shaped discussion in the UK long after the specific context in which it occurred. It led not only to the development of the kind of cooperative research associations adumbrated by Marshall (see, for example, Varcoe, 1981), but also, in the course of the war, to specific attempts by the UK government to encourage corporate research in key sectors alongside the development of a more focused approach towards the development of research and scientific manpower in the post-war period. In particular, it led to the creation in 1916 of the Department of Scientific and Industrial Research, responsible to a committee of the Privy Council. The model of the Department of Scientific and Industrial Research was specifically referred to in a post-war report of a committee chaired by Lord Haldane, which has come to be associated with the principle for the funding of science and which continues to be referred to as an abiding principle to which the government would continue to adhere in funding science and university research.

The *Haldane Report* of 1918 (Haldane, 1918) dealt with the issue of research as part of a more general view of the responsibilities of different central government departments and the way in which their functions could be improved. This covered not only research, but also national defence, overseas affairs, finance, production, employment, education, health and justice. The report nonetheless has been identified as the source of the Haldane principle, whose objective, it is claimed, is to ensure that decisions about the merits of different scientific lines of enquiry and the funding of different programmes and projects should be taken by peer review-based scientific research councils and without direct government involvement. This principle is frequently invoked and apparently stands full square alongside Marshall's first comment about the pursuit of knowledge at large, which we have discussed above. It is a moot point, however, as to whether Haldane ever formulated the proposition in the report in this way or that it was the intention of the report to do that (HM Treasury, 2006; Edgerton, 2009).

Most current references to Haldane refer to a single Haldane principle which asserts that the detailed decisions on the scientific content of particular programmes and projects should be taken by the research community (in current UK circumstances, the research councils) and without government involvement. The original discussion in the *Haldane Report*, however, relates to two sorts of principle. The first relates to research which should be carried out or supervised by a government department which has responsibility for discharging particular responsibilities and needs advice and research-based evidence to support the delivery of that policy. The second relates to what might be called 'research of general use', research which was not the responsibility of a specific department. For this purpose, the *Haldane Report* proposed a formal organisation, modelled on the newly-formed Department for Science and Industrial Research. Significantly, this department, formed, as we have seen, in the course of the First World War in reaction to the needs for scientific input into various aspects in the war effort, was specifically a department which worked under the direction of a government minister. So, it would appear that both of these principles involve the responsibility of a minister or, in the first case, ministers.

The link between the *Haldane Report* and the 'Haldane' principle of an arm's length position of government relates to the particular discussion of medical research which the report contained. In particular, the report looked in detail at the activities of the Medical Research Committee, which was the forerunner of the Medical Research Council and the precursor to the UK's multiple research council structure, spanning the different disciplines.[4] The Committee had its origins in the commitment of funds for the pursuit of research into tuberculosis as a result of a levy established under the National Insurance Act in 1911. As a matter of empirical fact, the report noted that the Committee had never confined its investigations to the particular areas which might be determined by the way in which the national health insurance act was being administered (governed in our terms by the first principle), but instead followed a very wide remit in allocating resources across the wide areas of medical practice and theory (governed by the second or general user principle). Although there was a minister responsible for health insurance, the report noted that the minister responsible for health insurance had 'never sought to control their work, or to suggest to them that they should follow one line of enquiry rather than another' (*Haldane Report*, 1918, para. 42, p.29, cited in HM Treasury, 2006). As was also the case with the establishment of the University Grants Committee in the same period, it appears that, although structurally these were responsible to ministers for the conduct of their affairs, the initial composition of their governing boards led to considerable autonomy in practice. The current emphasis on the role of government in asserting rights to intervene at strategic levels in determining the overall scale and allocation of funding has, therefore, always been explicit in the various developments of legislation affecting university funding since the turn of the last century.

There have, of course, been many turns and twists since the end of the First World War as the scale and cost of research have risen, its nature has changed, and returns from research have come under increasing scrutiny. Major changes occurred from the mid-1960s onwards following reports by Zuckerman (Office of the Minister for Science, 1961) and Trend (1963) [see, for example, the discussion in Salter and Tapper (1993)]. A particularly trenchant reassertion of the role of government in deciding the priorities to be pursued in the conduct of research funded by the government was expressed in the *Rothschild Report* of 1971. In relation to the relative roles of government and the science research community, Rothschild commented that

> ... the country's needs are not so trivial as to be left to the mercies of a form of scientific roulette

and that

> ... however distinguished, intelligent and practical scientists may be, they cannot be so well qualified to decide what the needs of the nation are, and their priorities as those responsible for assuring that those needs are met. (*Rothschild Report*, 1971, p.3, para. 6 and p. 4, para. 8, cited in HM Treasury, 2006)

At the heart of Rothschild's argument lay a view that there was a distinction between pure and applied research and that a great deal of R&D funded through the research councils was applied and not basic and should be funded directly by potential customers.

> The customer says what he wants; the contractor does it (if he can); and the customer pays. (*Rothschild Report*, 1971, p.3, para. 6, cited in HM Treasury, 2006)

The result was that a substantial portion of research council funding was transferred back to corresponding government departments. The transfer gradually eroded when it transpired, as might have been anticipated, that for a wide variety of so-called 'applied research', the customers were unable to specify clearly what was required, or understand fully the responses that they received from potential contractors (see, for example, Salter and Tapper, 1993). At the heart of this outcome lies a failure to recognise the deeply symbiotic relationship between so-called 'applied' and 'basic' research.

The extent to which applied and basic research interact and inform each other was clearly set out in Stokes's influential overview of the evolution of science policy in the United States in the post-Second World War period (Stokes, 1997). The recognition of this interaction, however, should not lead to an underestimation of the incentive issues which arise when considerations of use, and in particular the commercialisation of science, lead to a variety of interactions between universities and other organisations. These are acknowledged and are set out succinctly by Dasgupta and David (1994). They draw a distinction between the norms and incentives characterising the 'republic of science' with a concern for the pursuit of basic understanding (Merton, 1942), and the 'realm of technology' with its emphasis on questions of consideration of use and application. They stress *inter alia* the tension between the openness of the republic of science and the close proprietary nature of the realm of technology, a distinction characterised earlier by Ziman (1994) as CUDOS *vs* PLACE. CUDOS stands for:

Communalism – the connective nature of science and the publication of results at the earliest opportunity.

Universalism – participation should be open to all competent persons irrespective of nationality, origin, race etc.

Disinterestedness – the impartial presentation of results without personal interest in their acceptability.

Originality – this is the claim to novelty and not the simple reproduction of previous results.

Scepticism – all research claims subjected to critical scrutiny in testing.

As Ziman (1994) pointed out, this ideal typical *schema* is essentially based on the attitudes of individuals and their personal conduct. As Ziman (1994, p.178) puts it, 'this scheme defines and celebrates an individualism that is clearly inconsistent with the corporate spirit of non-academic R&D'. This is, in his view, because of the basic assumption that individuals in non-academic R&D are pursuing the development of organisational ideas with organisational aims. He proposed an alternative acronym summing up non-academic R&D, which is PLACE (standing for **P**roprietary **L**ocal **A**uthoritarian **C**ommissioned and **E**xpert). In this *schema*, local refers to the specific connection between types of knowledge and particular applications in a particular organisation as compared with the universal and more basic kind of knowledge which may lie behind the development of that particular local application.

The extent of tensions between these ideal type classifications of the norms of acceptable behaviour and their associated incentive structures depends critically on the institutional format within which both university and industry research activity occurs. It has, of course, been argued that underlying forces affecting the nature of the commercial and the university research endeavour have forced increasing contact and convergence between them in the course of the late twentieth century (Ziman, 1994; Shapin, 2008). On the one hand, the ever greater resources committed after the Second World War to the expansion of the university system in the UK, and the increasingly expensive nature of certain big science aspects of it have led to increasing government pressures in pursuit of budgetary control, accountability and management. This readily translated into an argument about the utility of large-scale expenditure on science and research and the relative value of the funding of different kinds of research spanning humanities, the social sciences, and the applied and natural sciences. These tensions became the more acute the greater the perception that funding for public research might have plateaued into a steady state in the 1970s (see, for example, Ziman, 1994). These issues, of course, lie at the heart of the Mode 2 exposition of the changing nature of knowledge production and exchange.

University–industry links in the context of R&D

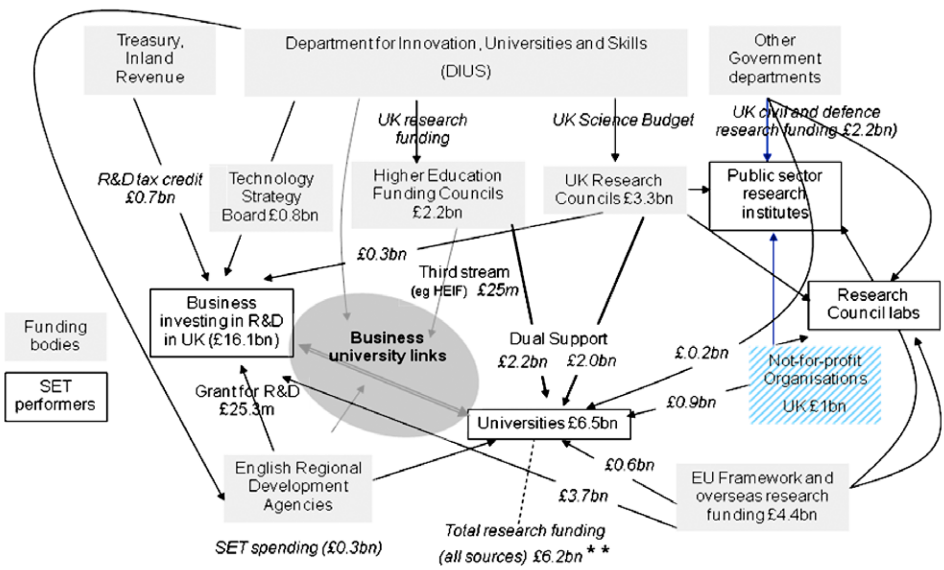
Since the original publication of the Mode 2 model, the analysis of the role that universities and the 'commercialisation of science' play in economic performance at sectoral, national and regional levels has become a growth industry (Malerba, 2004; Edquist, 2005; Mowery and Sampat, 2005; Yusuf and Nabeshima, 2007). One important outcome of this research has been to show that when businesses are asked to identify their most frequently used and important sources of knowledge for innovation, universities are low on the list. Thus, in a recent comparison of the United Kingdom and the United States using a sample of over 3500 businesses, it was shown that out of 18 possible sources of knowledge, universities ranked fifteenth in the UK and fourteenth in the US in terms of frequency of use. The same was true in both countries for the small high-technology innovating firms on which so much emphasis is placed in developing the triple helix notion of the entrepreneurial university. A similar outcome emerged when businesses were asked to rank sources of knowledge in terms of importance rather than use alone (Cosh *et al*., 2006; Cosh and Hughes, 2010). In both countries, internal knowledge within the business, customers, suppliers and other businesses were the dominant sources. These were followed by a large group of intermediating institutions, including trade associations, environmental and standard setting bodies, and public and private sector consulting and advisory bodies. This is consistent with earlier studies for the US (e.g. Cohen *et al*., 2002) and with evidence for the EU and Australia based on other innovation surveys. The production of knowledge in relation to innovation is thus heavily dominated by the commercial sector. Internal sources still rank very high, which is consistent with a still low penetration of the open innovation model, while universities are not in general dominant players, which is inconsistent with simple interpretations of the triple helix model.

Further analysis of these survey data for the UK and the US probed the extent to which sources were used in combination. This showed that in keeping with the distributed innovation interpretation of Mode 2 and of the open innovation literature, businesses rarely used one source alone. Although they were the most frequently used and most valued source, less than 3% of business relied on business sources alone. In both countries, they were combined with the use of intermediary institutions, and private and public sector research base institutions. This points to the need to understand the particular combinations which are most suited to particular sectors or types of business and not to treat universities as the most important source of knowledge nor one whose contribution can be assessed by examining it in isolation from others in a distributed system.

Another approach to placing universities in context in knowledge production is to locate university–industry links in the system of funding using the flow of R&D. While recognising that R&D expenditure is only one element in innovation and commercialisation, the analysis (shown in Figure 1) serves an important heuristic purpose. It identifies both the absolute and relative levels of public and private funding as well as the complexity of possible policy levers when attempting to use government funding to enhance the commercialisation of science.

In Figure 1, the shaded boxes are the direct and indirect providers of funding for research in the UK while the unshaded boxes are the principal performers of research. Indirect providers are institutions, such as TSB or the research councils, which allocate funds granted to them by central government for research purposes. The cross-hatched box covers not-for-profit organisations. These are major net providers of funds into the UK innovation system, as well as recipients of funding. The medical research charities are particularly significant here.

Figure 1 shows that universities carried out £6.5 billion worth of research activity in 2007–2008. The structure of the diagram allows us to see the many potential



* The data for business relates to the calendar year 2007 and for government and higher education to the financial year 2007-08

** Total sources for university research excluding self funding are as follows: Abroad £0.6bn, Business £0.3bn, Charities £0.9bn , Funding Councils £2.2bn, Research Councils £2.0bn, Other government £0.2bn

Source: Updated and revised from Hughes (2007, p.81); calculations based on ONS (2009).

AQ9 **Figure 1.** Funding and performing R&D in the UK in 2007–2008: university–industry links in context and actual ways in which funders of this research interact with the university science base. Of the total of £6.5 billion spent, around £0.3 billion was financed from within the sector itself. The remainder was funded predominantly by government. The commercial and industrial sector funded a minor part, amounting to around £0.3 billion. The core government funding is provided through the dual support system. The two mechanisms in the dual support system are direct funding through the higher education funding councils (which amounted to £2.2 billion in 2007–2008) and competitive research council funding (amounting to £2 billion in the same year). It is worth noting that the £2 billion received by the universities from the research councils accounts for approximately two-thirds of the funding disposed of by the councils. Of the remainder, £0.3 billion went directly into R&D carried out by the business community, £0.8 billion to research carried out in the research councils' own laboratories, and the balance to public sector research institutes which were also in receipt of funds from UK government departments. It is interesting to note that the £0.3 billion directed to business is roughly equal to the amount business contributed to funding university research.

The distribution between universities of the education funding council grant is based on allocations linked to university size and performance in the periodic research assessment exercises, augmented in various ways by success in obtaining charitable and industry funding. The extent to which this source of funding may be used to enhance university–industry links and the commercialisation of science depends on a combination of incentives offered in the block allocation formula and the research assessment exercises, as well as the internal strategic policy of individual universities. The second leg of the dual support system is the £2 billion allocated to the university system through competitive bidding to the research councils. These allocate project- and programme-specific funds across the university base, and fund their own research council laboratories and public sector research institutes. The allocation of individual grants is on the basis of scientific peer review, but the extent to which they are related to specific university–business interrelationships depends on the attitude of the councils towards strategic programmes, as well as their focus on particular areas or patterns of interaction. It also depends upon the extent to which commercial impact is one of the factors affecting the allocation of research funding across the programmes and bids of the research councils. It is precisely the recent tension arising from the statement of the need to increase selectivity into strategic areas of funding and to enhance the potential impact of research as a funding criterion which has generated the debate alluded to in the introduction to this paper.

In addition to the dual support flow of funds, a third stream of funding has also been put into place in recent years aiming at the specific creation of capacity to enhance interaction between universities and outside organisations, including – increasingly – business organisations. There are no directly comparable figures corresponding to the year 2007–2008 for this sum, but for 2006–2007 the total amount received by universities in England by this mechanism amounted to £25 million (PACEC/CBR, 2009). The potential commercialisation leverage of third stream funding relates both to the basis on which it is rewarded and to the individual strategies followed by the institutions in the allocation of these funds. This is discussed in more detail below. In addition to direct government funding, the university sector in the UK also benefits enormously from the provision of charitable funding. This is particularly so in the case of medical research, where the Wellcome Trust plays a significant role and where the total funding from not-for-profit sources in 2007–2008 as a whole amounted to just under £1 billion. The balance of university funding comes from abroad, including EU programmes (£0.6 billion), from a variety of direct government contracts and sponsorship (£0.2 billion) and directly from business, though, as has already been noted, the amount is small (£0.3 billion).

It is important to note that the biggest 'doers' of R&D are in the private sector. Business enterprise R&D in the UK amounted to £16.1 billion in 2007–2008. Of this, £3.8 billion was funded from abroad and slightly less than £1 billion from the government through a variety of business support policies and the research councils. Government funding amounted to £0.8 billion in 2007 and, in addition, the UK business sector was in receipt of £0.7 billion worth of subsidy through the R&D tax credit system. The bulk of this support for business innovation was channelled through the Technology Strategy Board (TSB). The Technology Strategy Board is responsible for the administration of a number of formerly separate funding streams associated with the Knowledge Transfer Partnership Programme, the Knowledge Transfer Network Programme and the Grant for Collaborative R&D. Business was also in receipt of the Grant for R&D administered in 2007–2008 through the development agencies in England and Wales and equivalent schemes in devolved administrations.[5] The vast majority of business enterprise R&D is self-financed within the sector itself and from overseas.

Finally, it is important to note that the government spent £2.2 billion on funding research which it carried out itself. The scale of these expenditures has provoked an important debate on the extent to which such expenditures could be used to pull commercialisation through from the science base via public procurement R&D contracts along the lines of the US SBIR scheme (see, for example, Connell, 2006; Connell and Probert, 2009). The potential role of public procurement has been recognised in recent reviews of the UK innovation system and the responsibility for implementing pilot programmes in this area allocated to the Technology Strategy Board (Sainsbury, 2007).

Business enterprise R&D is extremely skewed in its distribution across sectors and across businesses. This is particularly important in considering the role that might be played in fostering R&D and commercialisation of science opportunities linked to the smallest businesses. Official statistics for 2006 suggest that of £14.36 billion *intra mural* expenditure on R&D performed by businesses in the UK in 2006, £11.6 million was accounted for by businesses employing more than 250 employees. Moreover, 29.7% was accounted for by the latest five R&D spenders and 49.7% was accounted for by the top 15 spenders and over 76% was accounted for by the top 100 spenders. These 100 spenders also accounted for 89% of the R&D activity funded by the UK government (ONS, 2008, Tables 18 and 26). In thinking about the direct leverage which this expenditure may have on commercialisation linked to the science base, it is clear that relatively few businesses will account for the major impact to be achieved via this route. It nevertheless appears that £2.7 billion of expenditure is accounted for by businesses with fewer than 250 employees. However, only £356 million of this was accounted for by independent SMEs, and the rest by subsidiaries of larger UK or overseas organisations. Insofar as R&D is considered to be a key indicator (and, of course, there are reasons to doubt this in the wider context of expenditure to support innovation), it is clear that independent SMEs play a relatively small role according to official statistics. While this may reflect the inadequacy of these statistics, even substantial margins of error would still leave a relatively small role for the smallest businesses. Smaller independent businesses would require an order of magnitude shift in expenditures to make up for quite small changes in the behaviour of the largest firms. This must be kept firmly in mind in thinking through the implications of the role that businesses may play in the funding of university activities and the commercialisation of science, and the impact that government policy may have when operating on different sizes of firms.

It is equally important to note that the distribution of research income across university institutions is also significantly skewed and this may have important implications across institutions for the incentive impact of commercialisation opportunities on various funding streams. It is not possible to complete an analysis for the whole of the UK university system to match that for the R&D statistics, but as a result of a recent analysis of the impact of third stream funding (PACEC/CBR, 2009), it is possible to comment on the distribution across the English university system. The distribution of university research-related income may be gathered from an analysis of data provided by the Higher Education Funding Council for England (HEFCE) and the Higher Education Statistics Agency. We can consider total research income from all sources, research funding resulting from the quality recognition awards emanating from the Research Assessment Exercise and, finally, as a measure of government support for the promotion of university–industry interactions, the most recent allocation of the Higher Education Innovation Fund (HEIF). There are 130 UK higher educational institutions in England. The top 10 in terms of total research income accounted for 55.2% of all such income and the top 10 recipients of quality recognition funding received 50.9% of all such funding. The top 10 recipients of quality recognition funding received 50.9% of all such funding. The reciprocal of the Herfindahl indices[6] for total research income and quality-recognised funding suggest that the distributions were equivalent to 28 and 24 equal sized universities, respectively. This is a high degree of skewness in the distribution. By contrast, the distribution of the HEIF4 allocations indicate the equivalent of 78 equal sized firms, a far more even spread.

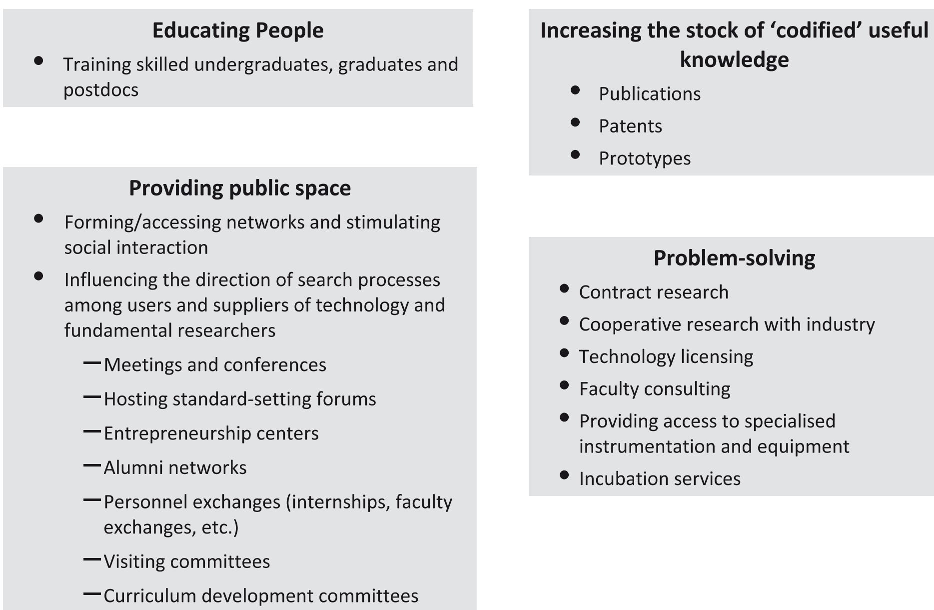
Two interpretations follow from this. The first is that, just as with business, relatively few larger research intensive universities dominate the research scene. The second implication is less obvious, but also important. This implication is that, for some universities, the incentive effects of trading off activities designed to enhance HEIF4 funding may be commensurate with expected gains from committing extra resources in pursuit of research excellence in an attempt to enhance QR. Thus, whereas the mean value of the ratio of HEIF4 to 2009 QR was 0.64, the median was 0.24 and the maximum was 7.07. The efficiency with which absolute levels of HEIF funding have been used and its relative impact across institutions is therefore worth exploring further in future research.

From the perspectives of Mode 2 and open innovation and their policy implications, a number of points emerge. The first is the relatively small role in absolute terms played by direct industry funding of university research. The second is the complex nature of the policy problem posed when attempting to change patterns of funding or the strategic allocation of funding between different objectives. The third is the impact that a focused policy on key players may have, given the concentration of the university and business research endeavour (when seen through the metric of R&D). The final point is that any attempt to change this system will be mediated through, and have impacts upon, the motivation and performance of the actors in this system and must examine the wider set of relationships beyond R&D that characterises the system of university–industry links. We turn to this in the next section.

The role of universities in the production of knowledge: university–industry links beyond R&D

Given the nuanced role of universities discussed in the previous section, it is important to ask what form knowledge exchange interactions take and which university roles are most valued. Figure 2 sets out a *schema* for analysing university roles in an innovation system which goes beyond the funding and conduct of R&D (Cosh *et al*., 2006).[7] It provides a categorisation in to four broad roles. First is the role of educating people. This includes the provision of skilled undergraduates, graduates and post-doctoral researchers. Second is the research role. This is the role of universities in increasing the stock of 'codified' knowledge. This takes the form of research publications, which represent the typical dissemination mode adopted by academics. It also includes patenting and prototyping. The dissemination of codified knowledge has long been recognised as central to the mission of universities, and business can clearly access and interact with the university base through it. They can also interact through co-authorship and co-patenting, and can co-produce knowledge as the third mission and triple helix analysis emphasises.

The two other boxes shown in Figure 2 cover problem-solving and the provision of what is termed 'public space activities'. In the problem-solving box, we find a wide variety of university–industry interactions. This can include contract research,



Source: Cosh, Hughes and Lester (2006).

Figure 2. University roles

consulting, and provision of access to specialised instrumentation, equipment and materials. This has also been a long-standing part of the mission of universities in many innovation systems. The fourth box contains what are termed 'public space roles' (Lester and Piore, 2004). These roles are easily neglected in policy debate since they are often 'softer' and less easily quantifiable than the activities in other boxes. Nevertheless, they represent a distinctive and important set of activities in the innovation system. They include, for example, the formation and accessing of networks which may span industry–university boundaries; the stimulation of social and community interactions through meetings, conferences and standard-setting forums. They include the promotion of personnel exchanges through internships, faculty swaps (as well as joint industry–academia visiting committees), and collaboration on curriculum development. The central idea behind the concept of public space here is that a university can play a catalytic role in which disconnected members of the community can meet, exchange ideas and develop common interests. These may then lead to the development of activities under the other three headings. This reflexive feedback loop is important since many more formal interactions spanning the other boxes may be facilitated and developed by the activities in this box.

This *schema* by itself tells us little of what academics do in relation to these activities; the potential trade-offs and conflicts; how academics perceive the relative importance attached to externally-facing activities relative to teaching and research *per se*; their own perceptions of the nature of basic and applied research and the existence, or absence, of cultural and related differences between academic and business which may inhibit the way in which these roles can be played. These issues are addressed in the following section.

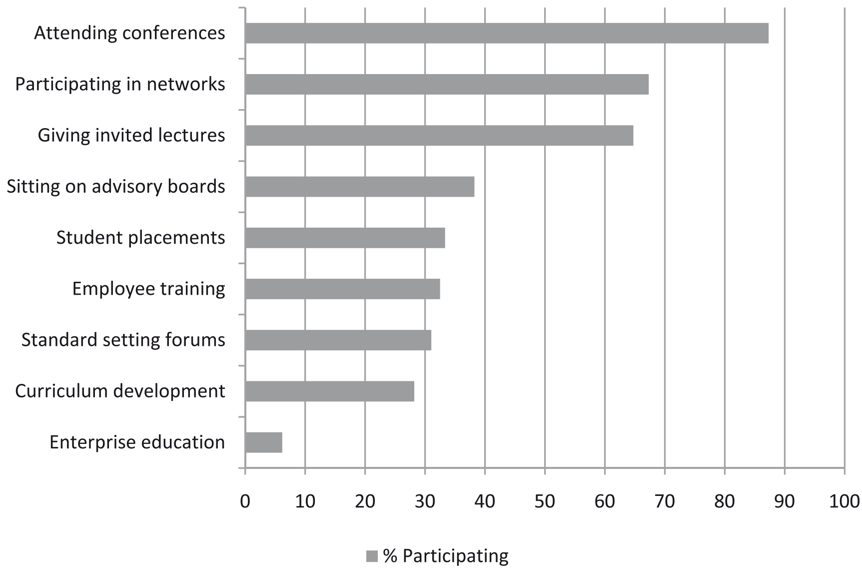
The view from the academy

The results reported here are based on the outcome of a web-based survey of UK academics carried out between autumn 2008 and summer 2009. The results presented below represent the returns from over 22,000 individual academic responses drawn from all UK universities and in all disciplines. This represents a response rate of 17.8% of a total population of over 125,000 academics surveyed.[8]

How do academics interact with external organisations?

The survey instrument asked respondents to indicate along which dimensions, if any, they had been involved with external organisations in the three years prior to the survey. For the purposes of exposition in this paper, these are grouped into *people-based activities*, *problem-solving activities* and *community-based activities*. It is obviously possible to consider other combinations and the classification of particular dimensions to each of these categories can be, and should be, a matter of further discussion. Nonetheless, it is a useful classification for our purposes here. We focus on the people-based and problem-solving categories.

We begin by looking in Figure 3 at the nine dimensions classified as people-based. By far the most common activity here is attending conferences, which well over 80% of our respondents indicated they had done. They were also heavily involved in participating in networks and giving invited lectures (around two-thirds of the respondents reported this kind of activity). Sitting on advisory boards

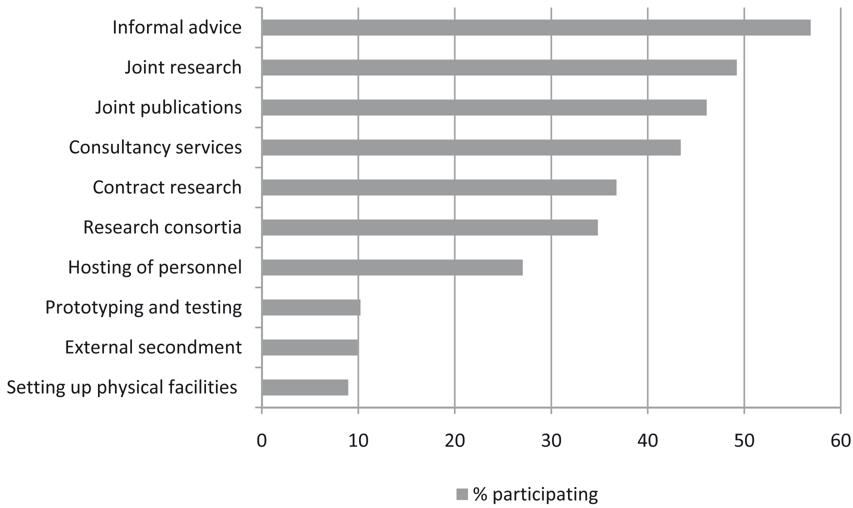


Source: Author's calculation from Hughes *et al*. (2010a).

Figure 3. People-based activities in the past three years

occurred in over 30% of cases. Curriculum development and employee training alongside student placements were also common activities, as was involvement in standard-setting forums, a particularly important kind of university–industry interaction. Taken as a whole, Figure 3 indicates an extremely wide degree of involvement by the academic community with external organisations across a wide spectrum of activities.

If we now turn to Figure 4, we see the 10 dimensions classified as problem-solving activities. Setting up physical facilities, while critical in certain particular science disciplines, is relatively infrequent. External secondment is also a relatively low activity in terms of frequency with 10% reporting involvement in this degree of activity. Since human interaction is an important means of intellectual and other knowledge exchange, its relatively small frequency may be a matter of concern. A similar level of around 10% of academics report involvement in prototyping and testing activity, which, as a specialised activity linked in particular to engineering and applied sciences, might not be expected to have been widely reported. All of the other activities have quite high levels of involvement, although typically lower than the most intensive people-related activities. Most notable is the fact that over one-third of the sample as a whole report involvement in research consortia, a similar proportion report having been involved in contract research, over 40% in the provision of consultancy services, somewhat less than 50% have been involved in joint research with external organisations, and well over 50% report involvement in problem-solving through the provision of informal advice. The role of informal advice is the most frequent form of interaction. This echoes previous research in which the business community cites this as by far the most frequent means of accessing advice for innovation (see, for example, Cosh *et al*., 2006). These high levels of people-based and problem-solving interactions dwarf activity in terms of



Source: Author's calculation from Hughes *et al*. (2010a).

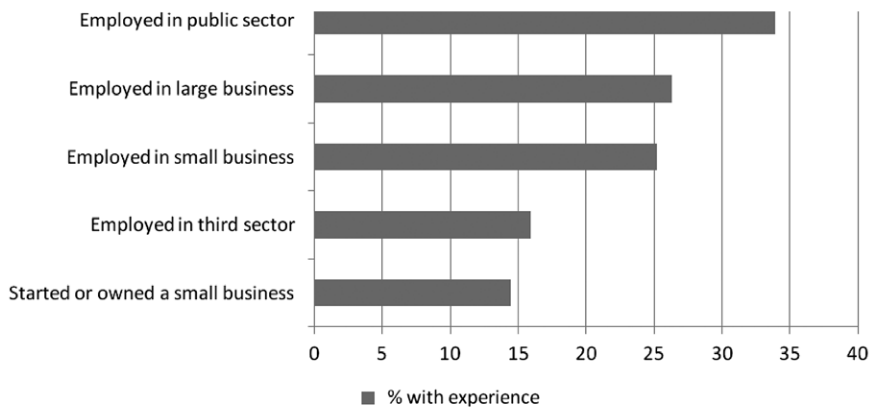
Figure 4. Problem-solving activities in the past three years

licensing and spin-offs from university research, where fewer than 10% of academics are involved. In the case of patenting, fewer than 5% are involved (Hughes and Kitson, 2011).

Commercial involvement and cultural attitudes

One factor which may influence the cultural attitudes of academics is the extent to which they have career experience with external organisations outside academia. Figure 5 provides a brief overview. It suggests that previous employment outside academia is quite common amongst academics. Just under 15% of academics reported having started or owned a small business, which is roughly the same as those who had been employed in the third sector. Small and large business employment involvement was reported just as frequently. On the whole, this suggests that academics have experience of the incentive and employment structures beyond academia in a high proportion of cases. It is consistent with mutual recognition of potentially conflicting norms and incentives.

If we look at more directly constructed attitudinal questions, it is possible to make some more precise statements about academic attitudes towards the relationship between higher education and the business community. Sample respondents were asked to rank on a scale of 1–5 (with 1 being 'strongly disagree' and 5 being 'strongly agree') their view of two statements about the links between industry and higher education, and between universities and third stream activities. The first of these asked for a response to the statement '*higher education plays a key role in increasing business competitiveness*', the second asked for responses to the statement that '*third stream activities have gone too far to the detriment of teaching and research*'. In general, Table 1 shows that UK academics tend to agree with the statement that higher education plays a key role in increasing UK business competitiveness. The score is 4 or above in all



Source: Author's calculation from Hughes *et al.* (2010a).

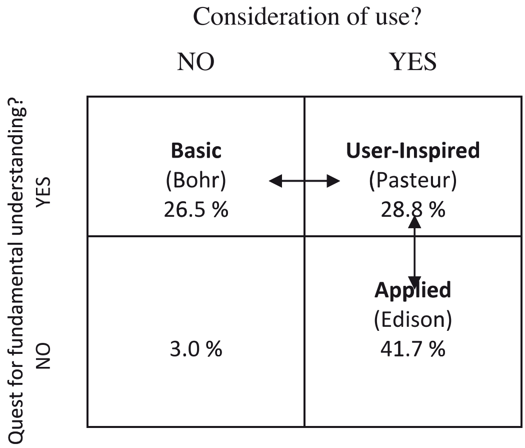
Figure 5. Experience outside academia

disciplines. In relation to the statement that '*third stream activities have gone too far to the detriment of teaching and research*' the result was just mildly positive. If we take 3 as a neutral response, it is the arts and humanities academics who feel that support for third stream activities is having a detrimental effect on teaching and research, followed by physics and mathematics, but the differences are small. These mean scores, taken as a whole, do not suggest an academic community deeply concerned with the erosion of their teaching and research activities, nor antithetical to the view that the role of higher education in the UK is important in promoting UK competitiveness. These mean scores, of course, contain a significant dispersion around the mean and large numbers who take opposite views.

Table 1. Academic attitudes to university–industry relations

	Higher education plays a key role in increasing UK business competitiveness	Third stream activities have gone too far to the detriment of teaching and research
Arts and humanities	4.0	3.6
Biology, chemistry, veterinary science	4.3	3.2
Engineering, materials science	4.5	3.0
Health sciences	4.2	3.1
Physics, mathematics	4.4	3.3
Social sciences	4.1	3.2

Note: Mean scores: 1 – strongly disagree, 5 – strongly agree.Source: Author's calculation from Hughes *et al*. (2010a).

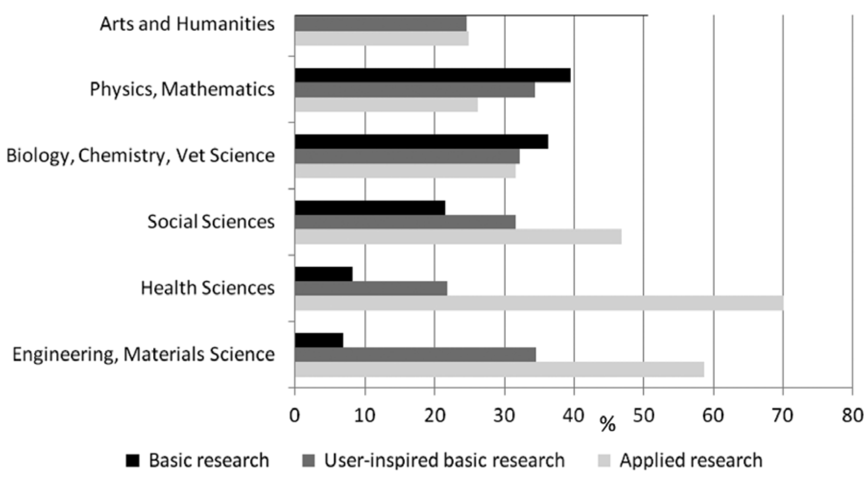


Source: Adapted from Stokes (1997). Author's calculations from Hughes *et al*. (2010a).

Figure 6. Stokes's quadrants: academic self-perception of drivers of research

Academic perception of the basic/applied nature of academic research

Each of our respondents was asked to classify his own research according to the standard elements of Stokes's quadrant analysis (Stokes, 1997) in which motivation is seen as based on either a quest for fundamental understanding or consideration of use. The questions were asked in the context of widely accepted definitions drawn from the *Frascati Manual*. In terms of kind of research undertaken, it is clear that the overwhelming self-classification of the research of academics in the UK is that it is applied or user-inspired basic research. Figure 6 shows that applied research was the self-classification of over 40% of the sample and user-inspired basic



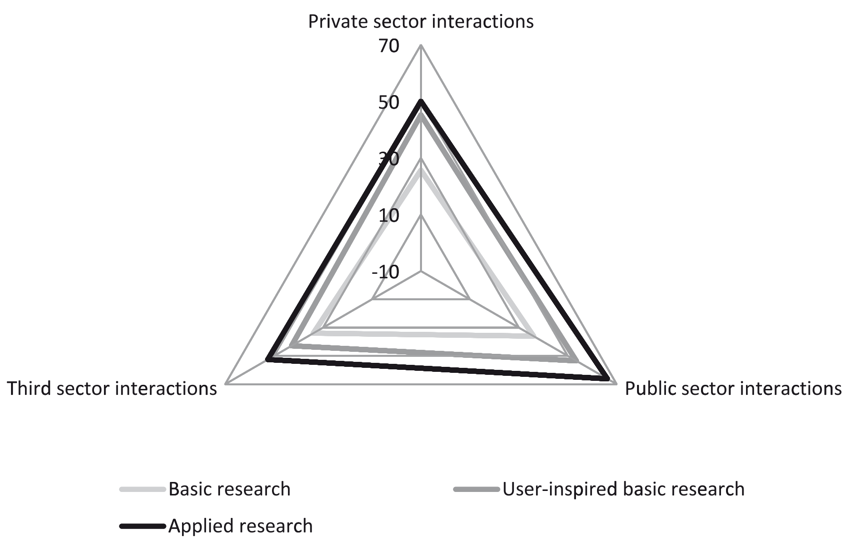
Source: Author's calculation from Hughes *et al.* (2010a).

Figure 7. Stokes's quadrants by discipline

research just under 30% – slightly higher than the proportion that reported undertaking basic research.

If we turn to the pattern by discipline (which is shown in Figure 7), some interesting results emerge. If we focus on basic research, it is apparent that this is reported most frequently in the arts and humanities, physics and mathematics, biology, chemistry and veterinary science. The contrast with this is to be found in applied research, where the health sciences and engineering and materials science followed by the social sciences report this as a dominant self-classification. User-inspired basic research is more evenly spread across the disciplines, but in every case (except arts and humanities) emerges as an intermediate category between basic and applied in terms of frequency. While these results may be consistent with some reasonable priors (e.g. in relation to health sciences, engineering and materials science), the patterns they reveal lead us to expect significant differences in attitudes towards the funding of different kinds of activity across disciplines.

Another way of looking at the relationship between basic research, user-inspired research and applied research is to consider the distribution of external activities by these kinds of self-classification. Figure 8 shows, for each type of self-reported research classification, whether the respondents reported external activities of any kind with the private sector, the public sector or the third sector. As might be expected, those who classified their research as applied on average have a higher likelihood of external activities involving each of the private, public and third sectors, followed again, as might be expected, by user-inspired basic research. It is, however, worth noting that even those whose research activities are self-defined as basic nonetheless report significant levels of activity involving external organisations. In approximately a third of cases, this is activity involving the public and third sectors. Those involved in basic research are least involved with any type of



Source: Author’s calculation from Hughes *et al*.(2010a).

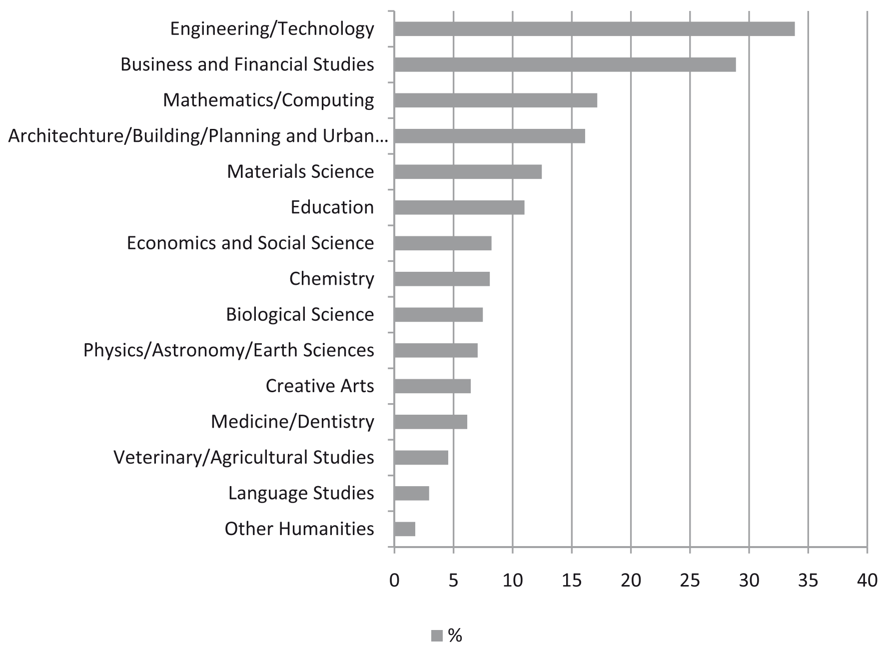
Figure 8. Percentage of academics reporting public, private or third sector interactions by type of research

interaction with the private sector. Even here, however, a quarter of the respondents reported at least one form of external organisation interaction. Finally, it is also important to note that the academics responding to the survey overwhelmingly report positive impacts of interactions upon their teaching and research (Abreu *et al*., 2009; Hughes *et al*., 2011).

What do companies think?

This section draws on the results of a stratified sample survey of UK businesses of all sizes and sectors.[9] A total of 21,200 firms from across all sizes and sectors in the UK economy were surveyed in the period July–September 2008. The first mailing went out on 7 July 2008 and the final set of prompt mailings was posted on 12 September 2008. From the total of 21,200 surveyed firms, 2357 useable responses were received, a response rate of 11.1%, which is comparable with recent postal surveys in this area. The results reported here are on data which have not been grossed up to national representative samples. The sampling approach deliberately oversampled among larger firms so as to capture useable numbers of businesses. This is essential given the highly skewed nature of the size distribution of UK businesses.

There is a strong emphasis on science and technology in most discussions of the nature of university–industry links and the commercialisation of science. It is interesting, therefore, to ask which academic fields were thought to be most important by responding businesses in terms of their knowledge base and technological activity. Figure 9 shows, as might be expected and in line with most of the current



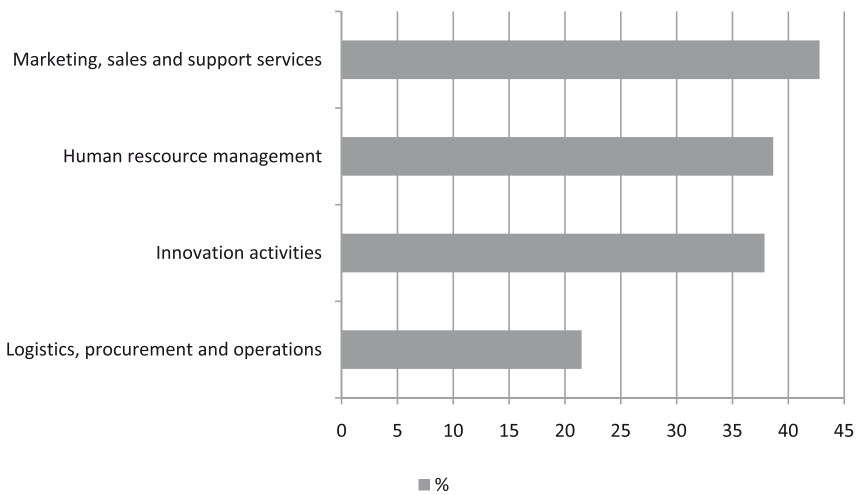
Source: Author’s calculation from Hughes *et al*. (2010a).

Figure 9. Which of the following academic fields have been most important for your firm in terms of knowledge and/or technological activities in the last three years?

policy rhetoric, that engineering and technology fields are most frequently cited. Thus, 34% of the responding firms indicated that this was the most important academic field. However, business and financial studies were very frequently rated as the most important academic field. They were followed by mathematics and computing and study of the built environment. Surprisingly, materials science was less frequently cited than might have been expected, given the current emphasis on this area. In general, humanities and arts activities are amongst the least frequently cited academic fields as being most important in relation to knowledge and technological activities. However, it is worth noting that the proportion citing the creative arts is not a great deal lower than the proportion citing chemistry or physics, astronomy and earth sciences.[10]

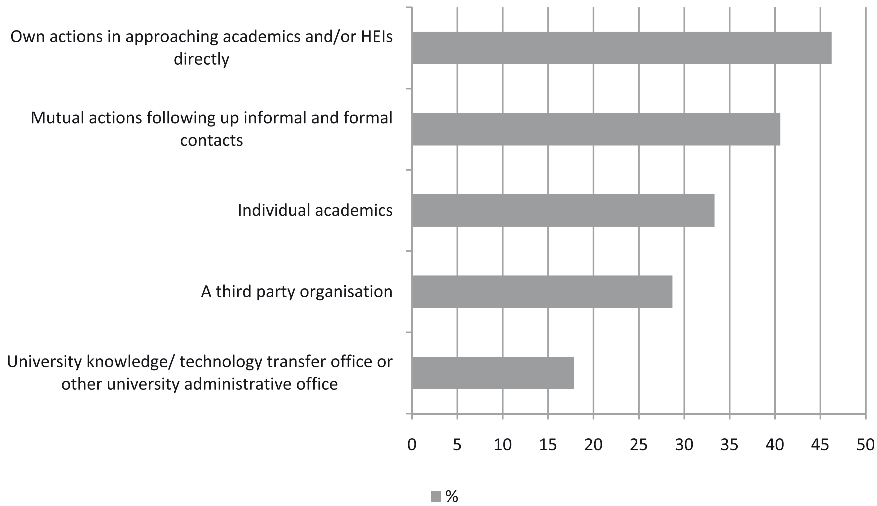
The pattern of ranking of importance is related to the reasons for interaction with the university sector. The reasons cited by responding businesses are shown in Figure 10. What is striking about this figure is that the two leading reasons for interacting with the university sector are associated with human resource management and a range of service-related activities. This is higher than the proportions reporting that their interactions were driven by the innovation-related activities of technology development and the introduction of new products and/or processes. Thus, it appears that technology is not the dominant reason for interactions and that the university sector provides services across a full range of business needs.

A striking result from the survey of academic attitudes and their relationship with external organisations was the significance of informal interactions. This response has also been recorded in a number of recent surveys on the behaviour of innovating firms in the UK, the US and elsewhere (see, for example, Cosh *et al.*, 2006). Figure 11 provides a wider overview of the ways in which interactions with higher education institutions are initiated when seen from the perspective of individual businesses. The data in Figure 11 are also interesting from the point of view of trying to gauge the importance of formal modes of mediating interaction (including



Source: Author's calculation from Hughes *et al*. (2010a).

Figure 10. Does your motivation to interact with higher education institutions (HEIs) have to do with the following primary activities in the value chain of your firm?



Source: Authors' calculations from Hughes *et al*. (2010a).

Figure 11. Are your interactions with academics and/or higher education institutions (HEIs) initiated by the following?

university knowledge or technology transfer offices. These have been the subject of considerable policy support in the UK in the past decade). Over 45% of the businesses responding to this question claimed that they had approached individual academics and/or higher education institutions directly. In approximately 40% of the cases, mutual actions following up informal and formal contacts had been the source of generating the interaction. In a third of the cases, mutual actions had been initiated by individual academics. Figure 11 also shows the relative infrequency with which interactions are initiated by intermediaries, such as university knowledge or technology transfer offices. Fewer than 20% of the firms with interactions reported that intermediaries were the source of the interaction.

Constraints on interactions

It is interesting to ask which factors were reported as constraining the success of interactions with higher education by those firms that did have collaborative relationships. This is shown in Table 2, which reports responses from only those respondents who had reported an interaction. It is notable that the most frequently cited factors constraining interactions are not university-based. They are to do with the lack of resources in the firm to manage the interaction, rather than, for example, problems to do with the higher educational institution itself. Bureaucracy and inflexibility of HEI administrations is cited by around a quarter of responding firms compared with 44% citing a lack of resources to manage the interaction in the firm itself. Medium firms are the most likely to report experiencing difficulties in their collaborations as a result of insufficient benefits from the interaction.

Just under a third of respondents cited one or more factors related to lack of policy support at a regional or central government level. A general difficulty in identifying partners was also reported by 28% of the sample; surprisingly, most

Table 2. Have the following factors constrained your interactions with higher education institutions (HEIs) in the last three years?

	All (%)	Micro <10 (%)	Small 10–99 (%)	Medium 100–499 (%)	Large 500+ (%)
Lack of resources in the firm to manage the interaction	43.9	44.0	39.2	52.1	51.1
Lack of regional programmes that encourage interactions	32.9	36.3	31.9	36.1	28.7
Difficulty in identifying partners	32.4	28.1	31.9	38.9	34.1
Lack of central government programmes that encourage interactions	31.5	35.1	29.6	37.1	27.6
Insufficient benefits from interaction	31.2	30.4	28.3	41.7	32.2
Bureaucracy and inflexibility of HEI administration	25.4	26.3	23.2	26.0	30.2
Lack of experience dealing with academics and/or HEIs	24.9	19.0	21.7	28.8	38.6
Lack of interest by academics and/or HEIs	22.6	19.5	20.2	27.4	29.5
Incompatibility of timescales for deliverables	16.9	16.8	14.6	20.8	20.7
Cultural differences	10.6	10.3	7.1	9.7	22.4
Difficulty in reaching agreement on intellectual property	8.2	6.2	7.9	6.9	12.6

Source: Author's calculations from Hughes *et al*. (2010a).

frequently reported by the larger firms. There are clearly some businesses believing that interaction might be enhanced by further changes in the amount or type of institutional support at regional and national level, although they are in a distinct minority of respondents to this question. The final four rows of Table 2 are perhaps most revealing in terms of whether difficulties in interaction arise from cultural divergences. Difficulty in reaching an agreement on intellectual property rights is insignificant compared with all the other factors in the table. It is cited most often by medium and large firms, but hardly ever by small firms. However, intellectual property rights issues are likely to be generated in only a small number of interactions since most interactions do not involve technical knowledge exchange. Cultural differences are also less frequently cited than might have been expected given the debate on these issues. Larger firms are most likely to report this as a factor. Given the skewed distribution in the sizes of firm and the resources devoted to R&D, this concern is significant. Incompatibility of timescales, which is also a commonly cited factor causing difficulties, is relatively lowly cited compared with other factors. The general lack of interest on the part of academics and higher educational institutions is reported by 22% of the sample, and perhaps significantly by almost 30% of large businesses responding. This implies that interactions would occur more effectively if there was more interest.

Summary conclusions

There is a long history of assertions about the lack of connectedness of the UK university sector with industry and the development of innovative products and businesses from the science base. Seen in the context of Mode 2, triple helix or open innovation thinking, this implies a failure in the UK to develop appropriate structures and incentive mechanisms to build an effective knowledge production and innovation system. This perceived failure is often attributed to long-rooted differences between business and university cultures, an over-emphasis on 'basic' as opposed to 'applied' research, and a failure to develop entrepreneurial universities driven by commercialisation imperatives linked to licensing spin-outs and STEM-led activities. These arguments have been subject to periodic critical scrutiny, but continue to resurface. They do so, in particular, in the form of arguments which stress a conflict of interest between the academic pursuit of freedom of research direction and creative research on the one hand, and focused strategic research aimed at commercial objectives and economic growth on the other. These arguments are being thrown into sharp relief in the debate over the role of universities and the funding of research in the aftermath of recession and financial crisis.

This paper argues that the historical roots of the UK debate are to be found in questions of institutional design and the management of research funding organisations to mediate the interplay between so-called basic, and applied, research. It was also argued that government involvement in core resource allocation decisions has, in principle, always been embedded in the UK system, though practised with varying intensity at different times. It has, as the Mode 2 approach would suggest, undoubtedly become more pressing as the public funding of research has risen.

The paper argues that recent contemporary policy towards the role of universities in innovation has placed too much weight on the notion of an 'entrepreneurial university' model, a model in which institutional design emphasises new business spin-offs and licensing, and their emergence from disciplines within science, technology, engineering and mathematics (STEM). The paper shows that this is a narrow lens. University–industry links, in general, are much less frequently and less highly valued than other sources of knowledge for innovation. Customers, suppliers and other intermediary agencies and institutions dominate. Moreover, the paper shows that spin-offs and licensing are among the least frequent forms of university–industry interaction, certainly compared with people-based interactions through recruitment and other means, and with problem-solving and contract-based research. These are most frequently developed and mediated through informal, softer relationships, which permit a reflexive relationship between basic and applied research.

The main empirical section of the paper used new data to explore the nature of university–business interactions as perceived by the two key, non-government players in this game, namely individual academics and UK businesses. The paper also set their perceptions against a more macro-analysis, which showed the extent to which key R&D and research activities were located in the hands of relatively few major corporate and university institutions, the relative role of public and private sector funding and 'doing', and the development of specific third stream funding in the UK. The picture which emerges may be simply summarised.

First, most academics believe their research to be user-inspired basic research or applied research. In mathematics and physics and the arts and humanities, this is less likely to be the case. Academics also report a very wide range of interaction with external organisations. They are very 'connected' individuals in 'connected' universities, even if these connections are often hidden in the usual rhetoric (Kitson *et al.*, 2009; Hughes *et al.*, 2011). A critical question is whether they have the capacity for increasing the level of interaction further without prejudicing the current high standing of UK research, judged by purely academic standards. To the extent that large majorities of academics report a positive impact of their interactions on their research, this may be thought less likely. However there is a large caveat: there is a belief among academics that the emphasis on third stream activities may have already gone too far. There are also limits to the absolute capacity of individuals or the current system to take on further activity without hitting capacity limits (PACEC/ CBR, 2009). Equally, there are capacity limits on the business side too. In a result consistent with the findings of the Lambert review of UK industry–university links (Lambert, 2003), the paper shows that businesses regard the primary limitations in developing interactions to be their own internal capacity to manage these relationships and not cultural or institutional failings within universities.

Finally, the paper's results indicate the importance of taking a broad view across all disciplines (and not just science, technology and mathematics) in looking at university–industry links. There is an extensive pattern of business demands articulated across the full disciplinary landscape. There is also abundant evidence that relationships are initiated and articulated through personal informal contracts, rather than through formal knowledge exchange institutions.

Developing effective Mode 2 relationships in the UK and the capacity to exploit the opportunities of increasingly open models of business innovation poses a major policy challenge. It requires structures of funding and organisational design which enhance the 'public space' roles which encourage the reflexive interplay between the commercial and university sectors, and which avoid a simplistic distinction between applied and basic research in key resource allocation decisions. Therefore, the emphasis of policy must be on demand pull; policy must embrace the full range of disciplines; and it must carefully examine the incentive effects on individual academics and institutions of further attempts to develop an already intensive set of interactions.[11]

Acknowledgements

The author acknowledges support from the Economic and Social Research Council (ESRC) in partnership with the Scottish Funding Council (SFC), Department for Employment and Learning (DEL) in Northern Ireland, the Higher Education Funding Council for England (HEFCE) and the Higher Education Funding Council for Wales (HEFCW) under grant RES-171-35-0018, 'University knowledge exchange: demand pull, supply push and the public space role of higher education institutions in the UK regions'. Earlier versions of this paper were presented at the 2009 DRUID conference in Copenhagen and the Riksbankens Jubileumsfond symposium on changes in science and policy held at Noors Slott, Sweden, in October 2009. The author is grateful for comments from participants at both these events, to Michael Gibbons for encouragement to write this paper, and to the Riksbankens Jubileumsfond for support for participation in the symposium. He is also grateful to Michael Kitson for many helpful discussions on this topic, and to Isobel Milner for data preparation for this version of the paper.

Notes

1. Named after Lord Haldane and an interpretation by later commentators of certain recommendations of this report on the machinery of government (Haldane, 1918) and an interpretation of how the interpretation developed (Edgerton, 2009).
2. Abreu *et al*. (2009), Hughes *et al*. (2011) and Hughes and Kitson (2011) contain fuller details of the survey data. This paper addresses briefly the related issue of the relatively small role of universities as sources of knowledge for innovation. For fuller details on this, see, for example, Hughes (2007, 2008, 2009) and Cosh and Hughes (2010), which also includes discussion of specific policies.

3. See, for example, Mowery (1992) and, for a critique of 'declinist' interpretations, Edgerton (1996, 2006). Von Tunzelmann (2004) and Magee (2004) provide reviews for the periods 1860–1939 and 1939–2000, respectively.
4. The UK research councils currently consist of the Arts and Humanities Research Council (AHRC), Biotechnology and Biological Sciences Research Council (BBSRC), Economic and Social Research Council (ESRC), Science and Technology Facilities Council (STFC), Engineering and Physical Sciences Research Council (EPSRC), Medical Research Council (MRC) and the National Environment Research Council (NERC).
5. The subsequent abolition of the Regional Development Agencies in 2010 led to the Grant for R&D reverting to TSB.
6. The Herfindahl index is a commonly used measure of concentration. It is calculated as the sum of the squares of university shares (in this case in research income). Its reciprocal may be interpreted as the equivalent number of equal sized universities required to produce the calculated value of the index.
7. For a similarly wide perspective and schema of roles, see Mowery (1992), Nelson (1993), Rosenberg and Nelson (1994), Salter *et al*. (2000), Cohen *et al*. (2002) and David (2007).
8. For a fuller review of the survey and its findings, see Abreu *et al*. (2009), Hughes and Kitson (2011) and Hughes *et al*. (2011). The large sample sizes in the academic survey mean that *all* of the differences reported in this paper are statistically significant and discussion focuses on quantitative significance.
9. For a fuller discussion of the business survey, see Hughes *et al*. (2011) and Hughes and Kitson (2011).
10. For a more detailed analysis of arts and humanities see Hughes *et al*. (2011).
11. For a fuller discussion of the design and potential role of intermediate technology organisations in developing commercialisation interactions see Mina, Connell and Hughes (2009).

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