UNIVERSITY BUSINESS RELATIONS:
CHALLENGES AND PROSPECTS

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This lecture draws on joint work with Paul David arising from our membership of the Expert Group on Knowledge for Growth within DG12 of the EU Commission. The interpretation it contains is entirely mine, as are any deficiencies. Comments on subsequent drafts by Davide Consoli and Richard Nelson are much appreciated.
I have been invited to give this lecture to celebrate 450 years of the Friedrich-Schiller University of Jena. Such longevity says a great deal about the value of the university idea in general and the Schiller University in particular, and so I thought it appropriate to focus on a question that also has deep historical roots namely, “How is wealth created from knowledge?” This general and fundamental question contains a far more particular modern instantiation, a seemingly simpler question, “How should universities interact with business in the promotion of innovation?” Like many seemingly simple questions it precludes any simple answers, yet it turns out that the role of Universities in the innovation process identifies some of the deeper complexities of our knowledge based economies and the connection with wealth creation. Recently expressed concerns that the implicit contract between universities and society is being rewritten to require greater accountability for publicly funded research and greater evidence of the commercial exploitation of research also point to the importance of visiting the connections between wealth and knowledge. These of themselves are sufficient reason to explore the question this evening- Jena, the industrial and university home of Carl Zeiss, Ernst Abbe and Otto Schott provides the perfect location to do so.

The theme is further sharpened by the fact that universities are seen increasingly not simply as sources of knowledgeable students and potentially profitable ideas, a traditional view, but as direct contributors to national and regional economic development through the formation of spin off companies and technology licensing arrangements. The invention of ideas and novel understanding has always been central to university life and the invention of useful devices has often followed as a natural by product, especially in the disciplines such as engineering and medicine that are defined by pressing practical problems. But the charge that universities should be the vehicles of exploitation is new and problematic. Their ability to do so depends on factors extraneous to the pursuit of understanding, for instance, on access to venture capital and a capability to manage exploitation in a professional fashion. Commercial possibilities often depend on the strength of intellectual property protection for university inventions and from this flows the need to organise the processes of exploitation and set up technology transfer offices. These developments have the potential to radically change the nature of a university, not least by opening up new paths for career development, new claims on professorial time, and new sources of funds for research. The fact that

1 See Martin (2003) for a contemporary account of the changing social contract.
commercialization practices are far more advanced in the USA can lead European policy makers and educationalists to be guided by envious glances over the Atlantic without perhaps fully comprehending the difficulties of transferring specific institutional arrangements from one society to another. Thus the case is made that university and business interactions in Europe would be facilitated by Bayh-Dole style arrangements that allow universities to hold the intellectual property for discoveries funded with public money. Notwithstanding the fact that the growth in US university patenting in the 1970s predated the Bayh Dole Act and was concentrated heavily in medicine and biosciences, this is a treacherous line of reasoning for it takes seemingly simple reforms out of a wider historical and institutional context without recognising important structural differences between national educational and research systems (Mowery and Sampat, 2001, 2005). If these matters are to be addressed successfully they will require solutions compatible with wider institutional constraints.

Beyond the nature of a university and how it might evolve there are other, wider issues at stake. In particular, the desire to raise the proportion of Europe’s GDP devoted to R&D (the Lisbon agenda) may only succeed if ways can be found of raising the payoff to innovation in European firms. One aspect of this certainly relates to the ability of universities to make available their large, accumulated stock of knowledge and problem solving techniques to lower the costs of innovation and reduce the uncertainties faced by firms when they innovate. If the private rate of return to R&D can be so raised it is more likely that the Lisbon targets will be attained, and, perhaps more importantly, it will be more likely that European companies increase their international competitive standing in the face of low wage competition from China, India and emerging economies, on the one hand, and high tech competition from the USA, on the other.

I propose to tackle my question in two broad stages, reflecting first on the evolution of the modern European university, and, secondly, locating a discussion of university contributions to the innovation process in a wider context of the division of labour in knowledge production. Of course, I am conscious of great differences in the form of the university systems in different countries and even more that the connections between business and academy differ greatly across different fields of economic activity. These make generalizations difficult so the reader must bear this in mind in what follows. Before going further, we should also note that the context for university business interaction in Europe and more widely has changed greatly in the past three decades, perhaps more than in any other
comparable period of recent history. A by no means complete list of pertinent developments would include:

- the general demise of centralized corporate, fundamental R&D laboratories in manufacturing industry and the reorganisation of corporate applied R&D around divisional, near to market activities;
- the increased internationalization of R&D activity, as some large firms become more willing to engage with universities on a world wide scale, even to the extent of locating their research facilities overseas to capitalize on local research excellence;
- the continued increase in “knowledge based service” activities within EU GDP, with the nature and meanings attached to “R&D activities” in the service economy being quite different from those in manufacturing and other commodity producing sectors;
- the decline of defense R&D that took place with the ending of the Cold War, especially among the western European member states;
- the privatization or adoption of different ownership arrangements for many former public mission-oriented research laboratories, defense, metrology, etc, invoking new governance structures that placed them at arms length from politicians and public administrators;
- the emergence of new areas of science with potentially strong commercial potential, certainly biosciences, but also others such as new materials and nanotechnologies, combined with an increasing awareness that many innovation problems do not fit within single discipline boundaries and require inputs from social and management sciences for their resolution;
- a growth in the number of universities and number of students per university, combined with increasing financial pressures on university funding systems in general and the funding of university research in particular.

Taken together these changes represent a fundamental restructuring of the context of university business interaction in the innovation process. The changing mix of market and non-market actors, the new governance systems, and new pressures on limited resources all impinge on the possibilities of forming innovation systems that may yield the desired flow of opportunities to create wealth and human welfare from reliable knowledge. To give just one example of the changing structure of innovation related activity, we point to the effect of these changes upon the growth in the outsourcing of R&D by business; some estimates
suggest that 15% of corporate R&D is outsourced to either as joint research projects or as research contracts to meet contractor needs.\textsuperscript{2} It is hardly surprising, in the light of these developments that uncertainties about the role of Europe’s university system and its interaction with the business sector should have acquired great prominence in discussions of science, technology and innovation policies.

The Modern European University

It is commonplace to say that the modern economy is knowledge based but a moment’s reflection points to the vacuity of this notion. For all economies are knowledge based and could not be otherwise. The question is rather how is one kind of knowledge based economy distinguished from another and here the answer may lie in three directions: in terms of the variety of knowledge that is engaged; in terms of the processes by which the production of knowledge is organised, and its corollary the resources devoted to knowledge production; and, in terms of the purposes to which knowledge is put. In respect of each of these directions the rise of the modern university as a custodian of knowledge in Western economy and society has been of central importance; but universities are not alone in this role, a wide range of other agencies, private firms, public research laboratories for instance play an important role and have done so increasingly since the turn of the 19\textsuperscript{th} century- as Whitehead expressed it- coincident with the invention of the method of invention.

Michael Gibbons and colleagues (1994) in reflecting on these developments make a distinction between two modes of knowledge formation, modes that are complements not substitutes. In mode I, the traditional discipline oriented and organised research process in University departments looms large, physics, chemistry and engineering are its exemplars. In these disciplines clear methods exist for the verification of novel knowledge claims and the driving forces in the evolution of knowledge are the problem sequences that are cumulative and internal to the discipline. Broadly speaking, disciplines develop through their own internal logic and the respective practitioners are usually keenly aware of the boundaries which determine the limits to the content of that discipline and the rights to professional recognition within it. The productivity of this mode of organisation in terms of the growth of

\textsuperscript{2} See Howells, 1999.
fundamental knowledge in science and engineering has been quite remarkable, a fact that scholars began to point to with increasing awe in the 1960s (De Solla Price, 1963) as universities absorbed increasing amounts of the research bill in advanced nations. But there are many forms of knowledge that mankind lays claim to and so it has always been the case that science is not the only category of knowing that we need to recognise as socially valuable, neither can we accept that the only reliable and useful knowledge is produced by its methods. Technological knowledge is not to be judged by its conformability with immutable laws of nature but with a much more diverse test namely does the knowledge lead to results that work in a specific context. Similarly economic knowledge of what constitutes a viable activity and how to organise it is judged by no epistemic canon but simply by the test of profitability - at least under the rules of market based capitalism. Thus the appearance of mode II knowledge, the process of production of which is characterised by four features: the synthesis of ideas from different disciplines; the overwhelming importance of the context of application in shaping the process of collaboration in knowledge production; the great diversity of the organisations that contribute to solving problems in this mode; and, the increasing role of criteria external to science in determining the incentives to and assessment of the resulting outputs. The fact that the two modes are complementary, and the fact that mode II has always existed, and indeed surely predates mode I by centuries, should not cloud the importance of recognising the changing relative importance of the two modes for it is this rebalancing of activity that raises questions about the nature of the established mode I traditions. This is particularly so in terms of current concerns about the role of universities in the innovation process and it is hardly surprising that this question should lie at the core of much thinking on innovation policy. Questioning the role of the University is, however, not a new sport.

In 1963, Professor Clark Kerr, then President of the University of California, delivered the Godkin Lectures at Harvard on the theme “The Uses of the University”. He pointed to long standing differences in the concept of a university after 1800\(^3\): ranging from, Cardinal Newman’s liberal ivory tower (the Oxford model) with the humanities at its centre, the disinterested pursuit of truth its method, and the rounded intellect its product, as compared to Humboldt’s vision (the Berlin model) in which philosophy and science form the core, with

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\(^3\) Universities that were established from the end of the 12th century onwards (Bologna, Paris, Oxford as exemplars) had strong ecclesiastical links and purposes, a bond that naturally began to weaken with the Renaissance and the rise of science and technology in the 17th century. See Ruegg (2004) for further essays on this theme.
autonomous professors leading research and independent students learning becoming the method, and the valuable specialist the product. The American system drew on both strands but by the 1930s was adding a new dimension, the professional school that, at its worst, in Abraham Flexner’s opinion, served merely as “a service station for the general public” (quoted from Kerr, p.5)\(^4\). Not only differences in academic organisation and substance are present here, fundamental and long standing differences in the relation between universities and their nation states are also extremely important: most continental European universities are effectively part of the machinery of government and their academics career civil servants, a model that could not contrast more strongly with the almost complete separation and autonomy of the Anglo Saxon model of university-nation state relations in the UK, its former colonies, and USA\(^5\). Behind these different meanings of the university lies a deeper issue encompassed by the utilitarian view of knowing, traceable to Francis Bacon, that Universities have a duty and a purpose to further the welfare of human kind in whatever ways are practicable: the view which is fundamentally counterpoised to and inconsistent with the idea of the University as an ivory tower, the haven as Leibnitz put it of “monkish pursuits”\(^6\). The tensions created by the utilitarian view are well reflected in the rise of engineering and other industrially oriented disciplines (chemistry for example) into the traditional universities in the 19\(^{th}\) century and have been well documented by Guagnini (2004), not least in relation to the search for status, and the financial demands made by laboratory based work on traditional financing and governance structures. One solution to the dilemmas was the creation of different models of technical university or engineering school in France and Germany and subsequently in the UK and USA. In the later, the land grant college movement initiated by the Morrell Act of 1862 (and the subsequent Hatch Act of 1887 establishing a national system of agricultural experiment stations) led to the formation of universities and technical organisations almost exclusively preoccupied with solving the practical problems faced by

\(^4\) The reference is to Flexner (1930) on which more is said below

\(^5\) That Australia, New Zealand, Hong Kong, South Africa followed a British but note not an Oxbridge model is scarcely surprising. More interesting, perhaps because unexpected, is the influence of the French model on the newly independent Latin American countries in the 19\(^{th}\) century and the influence of the German model on the USA, the universities of Chicago and Michigan as well as Johns Hopkins being notable examples. In neither case is the colonial link present. On this see Shills and Roberts (2004). Several of the early University presidents in the USA studied in Germany (Eliot at Harvard, for example) and the State of Michigan contained a large German speaking population which may have been a factor in that case. As Shills and Roberts point out, this is a matter of German influence not the copying of a German template.

\(^6\) The complementary viewpoint espoused by Francis Bacon and others that the pre 17\(^{th}\) century university was a scientific wilderness is effectively challenged by Porter (1996) in a carefully nuanced account of the interplay between the developments of science within and without the European universities of the time.
rural communities and local industries⁷. Many of these engineering oriented universities developed leading capabilities in the knowledge underpinnings of particular technologies, Manchester (UK) in textiles, Dakron (Ohio) in rubber, Stanford (California) in aeronautics, Jena (Thuringia) in optics and glass are examples that readily illustrate the theme. No one should doubt the close ties that have bound industry and academy in the pursuit of technological advantage. Nor should anyone doubt that the final responsibility for improving technical performance lies with firms. Universities aid and abet but they cannot be loci of innovation, for that requires engagement with the market process (Rosenberg and Nelson, 1993).

Not all agree that universities should be tied to the real world in the way that they have been. In a modern echo of the discord, Professor Minogue, has argued eloquently for the counter view that universities are not simply providers of education services in a continuum of knowing that runs from the fundamental to the applied. There are distinctly different kinds of reasoning in universities that distinguish them from the rest of society. He argues, Newman like, that the purpose of universities is not to produce knowledge to underpin progress and generate gains in relation to transient, practical affairs. The issue is not the application of fundamental truths but rather a remoteness from practical concerns that academics focus its attention not on the decision making needs of external agencies but rather devote themselves to the status and nature of what is known, to the cogency of evidence so as to underpin special understandings of the world that cannot be generated otherwise. In expressing this view, Minogue has much in common with the somewhat dystopian reflections of Abraham Flexner (1930) who considered Universities as places for thinking and research and the training associated with research. This Germanic vision of the modern university left no room for vocational “training activities”, (a false vision of a University and of its comparative advantage in an education system), in which category are included such disparate activities as teacher training, domestic science, journalism, optometry and business studies- he clearly did not approve of Harvard Business School! This is not to deny that the unworldly pursuit of abstract knowledge has potential practical benefits but it is the critical, scientific understanding of “industry, politics, law or medicine” (p342) that marks the contribution the University can make- their purpose is to educate not to train, to lay general purpose foundations not build specific structures.

⁷ It was only with subsequent legislation (the Adams Act of 1906) that the remit of the agricultural experiment stations was extended to include fundamental research (Rosenberg, 1961).
Debates of this kind reflect the inevitable fact that universities are not apart from the societies in which they exist, and so it is not at all surprising that as a society evolves so does the university system within it. If societies are knowledge based, universities cannot be expected to stand apart they are necessarily a partial reflection of the age. Thus the recent growth of research intensive firms and the growing demands of the State, especially post 1945, for answers to problems whether in the military or in relation to human health have greatly influenced what is expected of Universities. Newman’s world no longer exists, if it ever did. But other factors are at work too, factors generated by the universities themselves. Not least among them being the shifting balance of disciplinary knowledge, as reflected in the rise of different kinds of knowledge fields with different modes of accumulation- physics and social sciences in the first seven decades of the 20th century, and their eclipse by biological sciences, business studies and the rise of professional training in areas such as school teaching and accountancy, subsequently. It has always been the case that scientific knowledge is at the intersection of epistemic and practical interests and that the later materially affect the discipline structure of knowledge with departments of computing or textile technology, or industrial chemistry or civil engineering, or cardiology or oncology being part and parcel of the life of many universities. Thus the mix of activities in a university, as reflected in its mix of faculty, students and course offerings, is continually changing as is the changing pattern of the use of knowledge in society more widely. There is a deeper point of substance here. Knowledge develops in unforeseen ways, through processes that are evolutionary, cumulative and combinatorial rich in the immanent possibilities for the emergence of new lines of enquiry, it cannot in this sense be contained or stabilised. Universities play a major role in articulating this process and, in creating possible adaptations in economy and society in response to new knowledge, they are also inevitably required to adapt to what they create. The university turns out to be a model for the acquisition and dissemination of knowing that is relatively constant in the presence of enormous flux in the nature of what is known and deemed to be worth advancing8. Of lesser, but still considerable, importance is the set of economic adaptations that reflect the rise of the service economy relative to manufacturing industry and agriculture as sources of employment and sources of GDP. It is a remarkable

8 The corollary is the extreme uncertainty as to the precise way in which advances in fundamental knowledge emanating from universities will find practical application- who would have predicted that developments in mathematical physics would have led to innovations in financial instruments, for better for worse? Bush, 1945 is a clear articulation of the serendipity cum wealth creation viewpoint. It provides no basis for expecting that research may reasonably be funded with an eye to its economic impact. See Nelson (2004) for further elaboration.
fact, for instance, that many of the physics graduates of today find employment in the financial services industry in which their capacities for mathematical modeling of financial markets are put to good use. If these shifts in activity change the content of what constitutes skill and professional competence then it is inevitable that this will reflect back on the balance of skills that is considered to be the proper output of a university education.

There is another shifting balance that matters in this debate too, that between teaching and research, between concerns for conveying and conserving what is known and accepted, and concerns to challenge and change what is worth conveying. On the first view, the principle output of any university is the minds that it has disciplined, whether it is undergraduate or postgraduate. On the second, the principal output is the research output of the faculty and its measurement and ranking. That the two processes must be connected is not in dispute but the form of the connection frequently has been, and different solutions to this conundrum characterize different university systems. In France and Germany the research institute model flourished, in the UK the tension was sublimated, pragmatically, within undergraduate teaching, university departments, in the USA the innovation of the graduate school and professional training in research served the same purpose. The, Tayloristic turn of the past three decades, has further upset the former balance of time allocation by faculty to teaching and research, has admitted the possibility of a University professor who does not teach, and generally undermined long established notions of the behaviours that may be rewarded by promotion.

To return to Kerr, he foresaw only too well the beginnings of these trends from his vantage point in the American system, and his conclusion was that the University is displaced by the Multiversity, an organisation serving different communities (undergraduate, postgraduate, research, business and politics), that needs to be, as he put it, “as confused as possible for the sake of the preservation of the whole uneasy balance” (p.18).

If we reflect on the experience in Europe it is remarkable how much innovation and structural adaptation the university system has experienced during the past four decades. It is certainly not the conservative backwater that sometimes is depicted by reform-minded critics. Indeed, within the constraints of public policy and limited funding, Europe’s universities as a group

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9 See Ben-David (1977) chapter 5.
as well as individually continue to evolve, lead and respond to the challenges and opportunities opened up by new branches of scientific and engineering knowledge (bioscience, software, new materials and nanotechnology, being prominent instances), as well as by rapid growth in the numbers of students enrolled, and the conundrums posed by a broadening range of interactions with business entities and direct involvements in the creation of economic wealth from knowledge. A measure of the adaptations that are in train is provided by the vigourous contemporary debates that address the tensions between collegial and managerial modes of functioning, between alternative modes of funding, between the free and open disclosure of research results and confidentiality and the exploitation of IP ownership rights, and between appropriate modes of leadership and governance in organizations that have come to be judged more in terms of the services they provide to external clients rather than the support they given to internal research, scholarship, teaching and the curation of information resources.10

Before going further, some brief remarks on knowledge are relevant simply to make clear my own position. This is that knowledge is a property of human minds and cannot exist independently of those minds. What stands outside the knowing individual are representations of knowledge in written and spoken claims embodied in books, technical reports, academic papers, other visual media, the codified forms, and social conventions and rules, patterns of practice, the tacit forms. However, what makes economic and social life possible is the correlation of the knowing of different minds so that they can be said to understand in common when posed a question or given an instruction. Correlation of understanding occurs at many different levels but it is vital to the ability of individuals to coordinate their behaviour. The existence and continuity of an economic order depends precisely on these shared understandings. This is where education fits in and the great growth of public education and training from the late 19th century on speaks to the importance of correlating the understanding of diverse individuals. Universities however sit in an ambivalent role in this scheme. Correlated understanding may be essential for order but the decorrelation of understanding is essential to progress, for as Schumpeter convinces us, development depends on doing things differently, and differential action depends on differential knowing. The creative scientist and the radical entrepreneur have this in common; they share a world with fellow mankind but interpret that world differently. For

this innovative stance they are not always thanked, at least initially, but the challenge they represent to established claims to knowledge has been the basis for all of the growth in material and human welfare since the first industrial revolution if not before. Thus to say that economic development is contingent on the development of knowledge is simply to say that not everyone agrees that what is currently known is the only way of arranging the world. The challenge this raises is how to make disagreement possible and how to channel that disagreement in productive ways that enhance mankind in general. It is I think a remarkable property of the institutions that we associate with democracy and free society, namely science and the market, that they generate order through agreement but are entirely open for the prevailing agreement to be challenged.

Thus universities are remarkable sources of disruption to the status quo, and few indeed are the major developments in human activity in the past sesquicentury that are not reflected in the science and engineering curriculum of universities. It is not at all surprising that invention in terms of technique in business firms should be mirrored in terms of invention in terms of theory and ideas at remoter levels in universities. Changes in fundamental knowledge do have profound effects but not always directly and normally only when other kinds of translational knowledge are created to meet the needs of practical application. Universities play a major role in generating this bridging knowledge too in disciplines as varied as agronomy, medicine, computer science, aeronautical engineering, process engineering, metallurgy and business studies. This is not at all surprising when we recognise the three great strands of technical advance that underpin our modern standard of living are products of the discovery and harnessing of new forms of energy to displace human effort, the discovery of new materials in the environment and the synthesis of materials that have no natural existence. The growth of physics and chemistry is of central importance on all fronts but so are the bridging sciences. Peter Murmann (2003) has carefully documented these interwoven strands in his account of the development of the German dyestuffs industry, either side of 1900. The lead that German Universities had in teaching and research in fundamental chemistry and its instituting within an academic-industrial knowledge network was a material reason why major synthetic dye innovations occurred in German firms (and not in British or American firms). German firms could also expand on the basis of a ready supply of trained chemists to manage plants and conduct applied research in the new laboratories in the

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11 See Goldin and Katz (1999) for an account of the interplay between rapid industrial diversification and the diversification of university disciples from the late 1980s onward
industry. German chemical firms willingly funded university research but other bridging processes were important too, particularly the growth of academic and industry chemical societies with joint or overlapping memberships in which, as Marshall put it, “the mysteries of the trade become no mysteries” and ideas are readily interchanged and, crucially, become “the source of further new ideas”, a perfect Marshallian combination of restless knowledge and restless activity (1920, V, 10, 271). To provide just one more example out of many, Sally Horrocks has shown how a Department for Industrial Chemistry was established at the University of Liverpool in 1926 and followed a fundamental research programme in the chemistry of oils and fats that was of direct practical concern to major chemical and food processing firms in the region, one of these firms being Lever Bros. That company provided funds for project work and employed students who graduated from the department. However, as an indication of how the rational for a particular mode of interaction can change, in 1929 that company became part of Unilever, and the merger and the subsequent refocusing of the R&D strategy and relocation of the research laboratories of the new company to the Netherlands and Germany served to break the ties with Liverpool University. Indeed, the Department in Liverpool was closed in the early 1950s, by which time its external support network had largely disappeared.

There is one further dimension to note that is hinted at by Marshall. That is the necessarily restless nature of knowledge, the transient status of the current pattern of understanding. The nature of knowledge is that it leads to new knowledge and once this is reflected in formally organised research activities there is no knowing where it will lead. Isaiah Berlin captures the essential point: when writing of Vico and his understanding of history, we are told, “man is a self transforming creature, the satisfaction of each set of needs alters his character and breeds new needs and forms of life” he cannot therefore live his life “according to unvarying, timeless principles, for then there would be no growth, no historical change, only eternal repetition as in the lives of animals” (Berlin, 2000, p.65). The generation of new knowledge is not only a major source of economic transformation it is also a major reason why the future

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12 On the USA, see Mowery, D.C, Nelson, R.R, Sampat, B, and Zeidonis, A.A (2001), on Europe, Murmann (2003); also Nelson, R.R. (2004). As Murmann indicates the British synthetic dye industry benefited from an influx of German chemists while many of the leaders in the German industry had spent time in the UK to familiarize themselves with the textile and traditional dyestuffs industries (op cit, pp.71-74).

13 See Horrocks, S.M. (2007). Examples of this kind can be produced almost at will., military R&D needs have played a large role in this respect, but so have the links that electrical and chemical companies focused on commercial market thought it useful to develop with particular individual academic consultants and university-based research institutes.
is so unpredictable and uncertain. A society need not be organised to this end, as surviving aboriginal societies illustrate (and they are knowledge based too) but post reformation and renaissance the Western world stepped on to a different path with enormous gains in material welfare but no possible knowledge of what its future held. If knowledge and economy are in a state of flux it is hardly possible for the universities to be isolated from this ceaseless movement.

We are left with a dilemma, that of the university as a conservative institution operating in and drawing its resources from a dynamic environment. For the successful prosecution of its activities the university needs internal stability, security and the continuity essential for the work of a body of scholars who are also inventors and explorers of ideas. How can that internal coherence be maintained in a world of multiple pressures and increasing concerns that universities become creators of wealth from knowledge? How is the internal mode of organisation to fit with the demands of the external environment? What kind of bridges can be built or is the division of labour between business and academe to be redrawn with the creation of new, as yet unspecified, organisational forms?

It is in this context that the contribution of Universities to the innovation process needs to be addressed.

Universities and the Innovation Process

One should say first that even when portrayed as disinterested producers of scientifically verifiable knowledge, universities have an impressive record as contributors to the process of innovation, in terms of the development of concepts, theories and instrumental procedures or through the supply of educated students available for employment in business and other walks of life. The chemical industry, the computer industry and the internet industries around it, and the pharmaceutical industry are monuments to the value of practical knowledge that engaged with fundamental work in universities. University business interaction in this context arises naturally; it is self organising and does not depend on universities taking any direct interest in innovation or wealth creation per se. But much of the recent debate is on different ground and reflects a belief that more can be done to positively enhance a university’s contribution to innovation, whether by establishing a science park, promotion of incubators, acquisition of intellectual property claims to university discoveries, creation of
technology transfer offices, or the facilitation of professorial spin out companies. These proposals beg the question that long established processes of self organisation can be improved upon. We will review recent evidence of the effectiveness of these developments below but before doing so it is necessary to step back and gain some much needed clarity on the issues at stake.

First it is necessary to follow Schumpeter in distinguishing invention from innovation. Invention is not the same as innovation. An invention is an assemblage of ideas directed at achieving some practical effect that must usually be embodied in a device or procedure, drug or software if it is to be realised. An innovation is the economic realisation of an invention, it is about the application of new combinations of resources to the economic process and it requires skills of entrepreneurship and business leadership quite different from the skills required to invent. In Schumpeter’s scheme there is no shortage of inventions to hinder economic progress rather it is the rate of innovation that is the rate determining step in the process of economic development. Indeed, even if the stocks of scientific and technological knowledge were somehow rendered stationary, invention and innovation could continue unhindered for many years. What is invented is only a small part of what is potentially feasible, and an even smaller fraction of actual inventions ever acquire the stature of innovations. Innovations require access to and command of many more kinds of knowledge and capability than are summed up by the phrase “science and technology.” Knowledge of markets, of organisation, and of the availability of factor inputs are key aspects of innovation, and the absence of these complementary inputs is the downfall of many a promising invention’s transformation into a successful product or process. Thus while the universities have become major producers of the knowledge required to generate the inventions that can be turned into innovations they are not organised and governed to be producers of innovations in their own right- they are first and foremost designed to discover new understandings: in this task they are naturally inventive. It is the unique role of business firms in fact to be the almost exclusive source of innovations in modern capitalism, and it is firms that have the incentive and governance structures to make innovation their central remit. It is the firm that it is charged with a difficult combinatorial task, bringing together and integrating the many different contributions required to solve any given innovation.

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14 After giving this lecture I discovered an article in the Financial Times (29/11/07) by Jonathan Guthrie “Business and boffins have a volatile chemistry” that captures very well the difference between being an academic inventor and being an innovator, and the consequent need for arrangements to bridge between the two processes.
problem. It is the firm that must marshal the resources needed to turn invention into
innovation and it has strong incentives to do so. Indeed, the firm that is to survive in a
competitive international market can only protect its market position if it innovates
continually so as to differentiate itself in a profitable fashion from its rivals. Schumpeterian
competition, profit and innovation based differentiation are at the heart of the business
process but are quite foreign to the workings of the university.

Secondly, our particular form of knowledge based economic system depends on a
sophisticated, evolved division of labour in the production and articulation of different kinds
of knowledge produced by different kinds of organisation distinguished by different goals,
different operating procedures and indeed different cultures. This division of labour is
neither arbitrary nor the product of chance. The consequence is that firms and universities
operate with quite different governance systems. Universities are part of open science, the
rule is to disclose and make findings available for critical testing of rival scientists, and
indeed academic rewards and prizes are based on priority in disclosure. This has an
interesting by product namely that the systems of reputation in peer reviewed science are an
effective signaling device, indicating to firms who might have access to the knowledge to
help solve particular problems. By contrast the knowledge acquisition processes in business
firms, are closed, the rule is to keep the products of research proprietary either through
secrecy or patent protection, and commercial prizes while based on priority too are tested not
by rival producers but by their consumers in the market. The rules of this division of labour
in science have proved to be remarkably productive despite the problems associated with
excessive conformity to research targets and the inefficient scheduling of sequential research
programmes (Dasgupta and David, 1994) and they have a simple consequence, the open
characteristics of science imply that it must be funded by public subvention while the closed
characteristics of commercial research suggest it is funded by the firm’s themselves.

The insight that our knowledge based economies are based on a division of labour in the
generation and use of knowledge for innovation is not of course new. Adam Smith pointed to
it over 250 years ago. When he wrote about a third class of division of labour, over and
above those within and between firms in the use and production of machinery and the
specialisation of task, he meant the division of labour in the production of knowledge for
invention, those
“philosophers and men of speculation, whose trade is not to do anything, but to observe everything; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects … Like every other employment too, it is subdivided into a great number of different branches, each of which affords occupation to a particular tribe or class of philosophers; and this subdivision of employment in philosophy, as well as in every other business, improves dexterity, and saves time. Each individual becomes more expert in his own particular branch, more work is done upon the whole, and the quantity of science is considerably increased by it” (Smith 1776, Cannan edition, p.11).

As with any division of labour, the effect is to greatly increase the efficacy of knowledge production processes but this comes at a price. Because each individual philosopher is more highly specialised the question of how the knowledge of different philosophers is to be coordinated becomes of paramount importance, for without coordination there is fragmentation and loss of communication, a failure to spread understanding. In other words the power of the division of labour as producer of knowledge depends on complementary arrangements for coordination of those efforts and their results, that is to say it requires knowledge to have the properties of a connected system. This perspective bears directly on the coordination of knowledge acquisition processes in universities and firms.

Much has been written on the concept of innovation systems but it is also noteworthy that Alfred Marshall in his *Industry and Trade* (1919) sketched the main features of what we would now call an innovation system by distinguishing different kinds of research laboratory, each type fulfilling a different role in an economy’s knowledge ecology. The ecology is articulated in terms of a tripartite classification of research laboratories, as follows: those of the first order, charged with extending knowledge in the large and normally the province of publicly funded universities those originators of scientific advances that revolutionise the methods of industry; those of the second order, charged with generating knowledge directed at the requirements of a particular branch of industry and organised either by single giant businesses or in collaborative association between businesses; and those of the third order, quality control laboratories for particular establishments that check that their output meets the
As with any division of labour, the functioning of the resulting system of production depends on how the specialized components are interconnected in this case, not by arms-length anonymous market transactions, but by personal scientific contacts and common reference to published bodies of highly codified information. Thus, the technical research laboratory of an industry benefits from keeping in touch with the chief scientific laboratories, and “the later may gain much and lose nothing” by keeping in touch with the industries whose methods may be improved by the fruits of fundamental research. Marshall’s thoroughly modern account of the innovation processes therefore is one in which advances in knowledge are made by different actors, having differentiated capabilities and specialisations, working in different kinds of organisation with different motives and distinctive methods.

The businessman as innovator is supported by the role of students, “men who labour not with reference to the attainment of any particular practical end, but in search of knowledge for its own sake” (Industry and Trade, II, 2, p.203). Further, Marshall suggests, that disinterested pursuit is generally richer in its societal and economic outcomes than knowledge that had been pursued for particular private and practical ends.

What Marshall doesn’t tell us is how this diversity of objectives and modes of functioning, funding and organisation, may encourage or inhibit the coordination process, other than to suggest that this is a growing commonality of interest and consequent collaboration between science and industry at the borderland between science and technique, which can perhaps be aided by public support. A possible answer is that the links between researchers and business managers are mediated by a rich skein of other forms of association in the form of discipline based societies, industrial cum professional associations, collaborate industrial research associations and so on. In the terms to be deployed later they are part of the ecology that bridges between the different minds and purposes within the different communities. In terms of the possibility of connecting minds with problems to minds with solutions, these bridging forms of organisation are surely crucial.

If the transfer of knowledge from universities to business could be fully and efficiently achieved through placing knowledge in the public domain there would be little need to consider the matter further. Because scientific researchers face strong incentives to publish

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15 Today we would include in the latter category the metrology laboratories and public or quasi-public “standards institutes” charged with setting and disseminating physical and technical standards, and checking compliance of products with specifications mandated by government regulations.
their findings, such information is readily accessible to firms that have the requisite scientific capability and managers of innovation projects need only “read the relevant literature”. This they do, but the issues are far more subtle. Not all of the knowledge possessed by scientists is placed in the public domain, and the unexpressed (tacit) components of knowledge matter critically in translating a generic scientific discovery or technological result into a specific, commercially viable application. Fundamental knowledge is too abstract in many cases to map onto practical problems in firms and a translational gap needs to be bridged. The problem of designing such inter-organizational connections and coordination of efforts in the sphere of information production and exchange that is relevant for innovation, a challenge that so preoccupies modern governments. The implication is clear, firms need to invest in absorptive capacity if they are to pose the relevant questions and recognize the relevant answers, and this absorptive capacity is based on the employment of qualified scientists and technologists, certainly in R&D activities but also in more operational positions in a firm. (Carter and Williams, 1961)

Critics of the role of universities and firms in respect to their performance in commercializing research results and exploiting the income-generating potential of the “knowledge assets” represented by their faculties and staffs, should reflect first on the fact that the division of labour between profit seeking business corporations and universities reflects both the quite distinct roles that these organisations fulfill, and, moreover the complementary between those roles. We can all understand that it would be as unwise to expect firms to behave like universities as it would be to expect universities to behave like firms. The division of labour is there for a purpose, it should be respected. How then is the bridge to be formed that translates invention into innovation?

Self Organisation or Positive Inducement

The thrust of the above observations is that the role of universities in facilitating innovation is not at all new or rare. Their role reflects sophisticated divisions of labour and instituted differentiation of organisation in which much interaction takes place through a process of local self organisation to enable faculty and business to come into contact and find that they

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16 The award of the 2007 Nobel Prize for physics to the discoverers (Albert Fert and Peter Grunberg) of what is known as giant magnetoresistance, is a case in point. Their disinterested fundamental research in the late 1980s became the basis for high density storage of information in electronic devices, making possible the iPod for example. However, the work only led to the invention of practical devices only after much developmental effort by IBM.
can fruitfully co operate in the solution of problems of innovation. The insight that the innovative performance of firms might depend upon the spontaneous and quite unpredictable way in which they build an external organisation of connections with universities and other laboratories suggests that university industry interactions in pursuit of business experimentation are not simply a product of the past two decades.

Survey evidence adds further support to the self organisation theme. Alan Hughes and his colleagues in Cambridge have done important work here drawing upon detailed surveys of practice in the USA and UK. What they show is that universities contribute to innovation performance in many subtle ways, most obviously through the supply of the trained minds of graduate employees, through research contracts, through the purchase of licenses, and through consultancy arrangements; an least obviously by being a public space for the organisation of conferences, for the conduct of professional scientific networks, and for a plethora of other routes to social interaction including periods of secondment between academy and industry. When surveyed the firms responded that it was informal contacts and recruitment of students that contribute most to innovative efforts, while licensing, research projects in universities and consultancies are numerically far less important (Hughes, 2007).

Broadly similar results have been obtained for larger surveys conducted for the USA. Thus Cohen et al (2002) conducted a survey of all R&D units in manufacturing firms and concluded that one third of projects made use of research findings from public research, and that the key channels through which university research influences industrial R&D are published papers and reports, public meetings and conferences informal information exchanges and consultancy although they note important differences across industries in the relative importance of different channels of interaction17. These self organizing but informal and diffuse channels are to be distinguished from formal R&D collaborations or other formal technology transfer arrangements and they are clearly of great importance and it will be a great mistake to undermine their operation. Recognition of this point by policy makers is it seems increasing. Thus, under the heading “The role of the universities in promoting business-university collaboration,” the Lambert Review (2003: p. 41), remarked on the growing role that universities (in the U.K.) have taken in their cities and regions during recent decades:

17 Cohen et al also find that recruitment of graduates is less significant an influence. The contrast here with Hughes’ results may reflect the different foci of the surveys, namely a broad focus on innovation in the later and a relatively narrow focus on R&D in the former.
“Vice-chancellors often have links with the CEOs of major local companies, with chambers of commerce, with their development agency and with NHS Trusts and other community service providers in their region. Academics work with individual businesses through consultancy, contract or collaborative research services. University careers services co-operate with the businesses which wish to recruit their graduates or provide work placements for their students.”

However, the thrust of this essay is that this too has always been so.

These findings on the self-organising structure of interactions find further corroboration when firms are asked to specify the source of the ideas that help solve innovation-related problems. Table 1 shows the outcome and from it we immediately see the relative unimportance in both countries of universities and other research laboratories whether public or private. As the table shows it is the internal efforts of firms that provide the most important source of ideas but external factors unconnected to universities are important too. Here the connections that are market process-mediated, links with customers and suppliers and indeed competitors, are far more important to firm’s innovative activities than are their links with the wider research system. Table 1 also points to the role of intermediaries that facilitate engagement between business and universities. These intermediaries typically are specialised research laboratories (some of which are privatized former public research laboratories or industry research associations) that have accumulated expertise in transfer sciences and the industrial technologies into which the latter feed.

It is precisely because information does not flow easily between unlike minds that such agents are able to play important (and profitable) roles in Europe’s innovative activities: variously called bridging organisations, technology brokers or boundary organisations, they serve not only to connect different components of innovation systems in responsive mode, but also perform pro-actively, by animating new connections that might not arise spontaneously. As exemplars of Marshall’s third type of laboratory, they provide a vast array of information and consultancy-based services, ranging from foresight exercises, to testing and quality accreditation, cross-disciplinary information

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18 Perkmann and Walsh (2007) provide a useful overview of the multiple forms of engagement between universities and industry, drawing on American and European literatures. They distinguish passive forms of connection (reading the literature or employment of graduates, for instance) from increasingly intensive forms or relationship the deepest of which involve collaborative research programmes. The full list of possibilities, in decreasing order of relationship, is as follows: research partnerships, research services, academic entrepreneurship, human resource transfer, informal interaction, commercialisation of (intellectual) property rights, and, scientific publications (loc cit., p.262).

integration and recombination for the identification of new potentially profitable areas of commercial product design and development. Nor should one forget the complementary role of the specialised technical and trade press, one of Marshall’s important sources of external economy.

Universities and Innovation Ecosystems.

In the light of the above it seems that the role of universities in the innovation process is far more complicated than might be thought. To further our understanding of this point it is helpful to explore an innovation systems perspective on university business interaction more fully.

Since any division of labour entails specialisation and differentiation it may be useful to think of the set of innovation related organisations as constituting an innovation ecology. Innovation ecologies in advanced countries are very rich, they include firms of very different sizes, universities with very different missions and a range of what we called above innovation intermediaries, such as consultancies and private research laboratories. However, the ecology is not a system as such, for what defines a system is the connection of components of the ecology for a purpose – in this case to solve innovation problems. Once connections are made we have an innovation ecosystem that operates in its own way depending on the members and the problems in view. The defining characteristics of a system require that its components are connected for different purposes, and, the possibility of multiple patterns of connectivity implies that any given ecology of components can be formed into very many different kinds of innovation systems of widely different scale and scope. That innovation ecosystems are shaped by national contexts of institutions, law and funding is obvious but it is not at the national level that the engagement with innovation problems occurs, rather that is at the level of individuals in firms, universities and other supporting organisations. A national ecology provides the basis from which particular innovation systems focused around particular problems can either self organize or, failing this, be deliberately encouraged to form by specific policy interventions. On this view there

20 Metcalfe J.S., 2007, ‘Innovation Systems, Innovation Policy and Restless Capitalism’, in F., Malerba and S. Brusoni (eds), Perspectives on Innovation, Cambridge, Cambridge University Press. As an illustration, the Alvey programme in the UK in the 1980s was an attempt to create a large scale innovation system for 5th generation computing by bringing together firms and universities in a programme of collaborative publicly funded research of a pre market – and thus pre innovation – nature.
is not one innovation system but rather an indefinite number, each one formed to solve specific innovation problems and dissolved when that problem has been resolved. What matters is the ability to deploy the ecology in the formation and reformation of different innovation systems. If innovation systems are transient and are constructed around specific innovation problems, then it is readily seen why firms, as the primary organisations that bring innovations into economic effect must play a central motivational role in the construction of innovation systems. Moreover, as the problems change so the contributors to any one innovation system will change too.

From a wider viewpoint it follows that two distinct problems arise, the richness of the national ecology and the facility with which connections can be made to solve innovation problems. Governments have clear responsibilities for the richness of the ecologies in terms of which areas of knowledge are commanded nationally but the ability to foster connections is rather more complicated

If we turn to the possibility of making connection to solve innovation problems it is clear that firms and universities must be open to the possibility of external interaction. Neither can be a closed world. As suggested above, the openness of a firm is unlikely to be independent of its employment of qualified scientific and technical staffs and any firm expecting to interact with the university science base must invest in the development of its own “knowledge base”. A firm must invest in the absorptive capacity to know what questions to ask, and who to address them to, and how to interpret the answers in the resolution of its innovation problems. This can pose an obvious problem for the connectivity of innovation systems, namely lack of business R&D or of scientifically qualified employees to enable firms to interact in a high quality way with universities.

It is also clear that internal organisation and the incentives to co operate also matter. The natural desire for commercial confidentiality in a firm does not fit easily with the rules of open science in the university system, indeed some authors have expressed deep concerns

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21 Rosenberg, N., 1990 is the classic reference to a large literature on absorptive capacity. A recent review by Agrawal (2001) is a useful starting point for the interested reader. See also Perkmann and Walsh (2007)

22 That is why it is important to increase business R&D investments and the commercial employment of QSTs as a complementary policy measure accompanying any increase in public R&D outlays, as is recognised in the EU Barcelona targets. Increasing public R&D without a commensurate increase in private R&D will severely limit university and industry interactions that can utilize the results of the former in pursuit of innovation.
that too close a degree of interaction between universities and firms can undermine the nature of academic research and subvert the public commons character of university research (Nelson, 2004). Size of firm makes a difference too. In the case of large and indeed medium science based firms it is difficult to see a problem. They are typically founded on science and employ or are even led by scientists. A few firms, mainly in pharmaceuticals, aerospace and electronics and computing have research laboratories in scale and scope to match the best universities, but they are the exceptions. Small firms, even if they are innovative may pose quite different problems since they will lack the resources to engage with the university system. On the academic side, rules of the game such as the legal regime to protect IPR, the policies of firms vis-à-vis employee inventors, and the specific reward and career progression norms that apply to academic careers, all contribute to shape expectations on the part of those working in universities regarding the payoffs from interacting with firms and other non-university organisations. Clearly, the organisational context in which their faculty work, and the structure of the institutionalized incentives and constraints are crucial to their connectivity with other agents and the productivity of their activities\(^\text{23}\), and act as powerful shapers of their propensity to interact across the research system in general and with business firms in particular.

It is in this context that a coherent theme of academic policy has emerged to promote a “Third Stream” or “Triangulation” of the University system, the purpose of which is “the explicit integration of an economic development mission with the traditional university activities of scholarship, research and teaching”. \(^\text{24}\). Third Stream activities are of many different kinds, and here it is important to distinguish those activities that seek the commercialization of university research (technology licenses, joint ventures, spin offs etc) from activities of a more socio-political nature that include professional advice to policy makers, and contributions to cultural and social life.\(^\text{25}\) What is significant about the current

\(^{23}\) Foray, (2004).

\(^{24}\) T. Minshull and B. Wicksteed, (2005). Activities of this nature are not linked solely to academic and industry interactions. The tripartite missions in health care to link biomedical research with clinical service delivery and clinical education across hospitals and university medical schools have been widely adopted in the USA and UK. In the later they are known as Academic Clinical Partnerships and they provide the framework within which much NHS funded research is carried out. Segal Quince Wicksteed, (2006).

debate is the emphasis on the commercialization activities. What is less well understood is design of arrangements for commercialization that do not inhibit the research and teaching functions, the primary function of any university. To overcome the barriers to connectivity by having university organizations become dependent upon commercialization of research findings, and behaving as a proprietary performer of patentable R&D is not sensible, as it would severely jeopardize the open science arrangements that are more effective for the conduct of fundamental, exploratory research – a function that must be fulfilled by some institution if a basis for long-run productivity growth is to be sustained (Nelson, 2004).

Thus, one should not presume there is a functioning “innovation system”, but recognize instead that the latter may be – or may fail to be an emergent property of the ecology formed by these differentiated institutions and their respective actual and potential capabilities, including the array of adaptive capacities for forming mutually productive interactions with one another. Whether that functional “systemic property” is emergent, or fails to yield a sustained process generating and diffusing technological and organization innovations should not be viewed as determined only by the characteristics and performance qualities of some particular class of institutions within the ecology.

**Conclusion**

We might reasonably conclude from the evidence that university-industry interactions are a normal part of the innovative process, that they arise spontaneously, that they form and reform unpredictably over time to address many different kinds of problem, and that the forms of connection are of many different kinds. This elaborate division of labour has worked well but its continued functioning depends on two crucial factors: the ability of the Universities of Europe to maintain an open perspective in the face of manifold resource and governance pressures; and, the willingness of firms to invest in innovation and develop the absorptive capacity to engage with the science base in academia. I conclude though on two notes of caution. Firstly, care should be taken in comparing the performance of individually selected institutions or the collectivity of universities in the EU with their seeming counterparts in other regions of the world, the USA in particular. Institutional complexities
do not usually travel well and a neglect of nuances and particulars is a recipe for misunderstandings and ill-considered policy commitments, they should be avoided. Secondly, innovation, is more than a matter of invention and so it is particularly important not to equate innovation policy with policy for science and technology. There is much more to the innovation process than R&D wherever it is performed. University-business linkages form only part of this process, albeit an important part and their influence on innovation cannot be independent of the many other factors at play.

References


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Table 1. High importance of sources of knowledge (% of users of that source)

<table>
<thead>
<tr>
<th>Company Sector</th>
<th>UK %</th>
<th>US %</th>
<th>Ratio (UK/US) x100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppliers of equipment, materials, components, or software</td>
<td>41.5</td>
<td>49.2</td>
<td>84.4</td>
</tr>
<tr>
<td>Internal knowledge within the company</td>
<td>79.9</td>
<td>84.5</td>
<td>94.6</td>
</tr>
<tr>
<td>Clients or customers</td>
<td>60.9</td>
<td>53.5</td>
<td>113.7</td>
</tr>
<tr>
<td>Knowledge within the group</td>
<td>59.4</td>
<td>50.7</td>
<td>117.1</td>
</tr>
<tr>
<td>Competitors in your line of business</td>
<td>27.7</td>
<td>20.8</td>
<td>132.9</td>
</tr>
<tr>
<td>Intermediating and Regulatory Organisations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consultants</td>
<td>12.5</td>
<td>26.2</td>
<td>47.7</td>
</tr>
<tr>
<td>Professional conferences, meetings</td>
<td>14.6</td>
<td>23.9</td>
<td>61.2</td>
</tr>
<tr>
<td>Trade associations</td>
<td>15.1</td>
<td>23.5</td>
<td>64.4</td>
</tr>
<tr>
<td>Technical/trade press, computer databases</td>
<td>21.5</td>
<td>26.5</td>
<td>80.8</td>
</tr>
<tr>
<td>Fairs, exhibitions</td>
<td>17.4</td>
<td>18.0</td>
<td>96.8</td>
</tr>
<tr>
<td>Environmental standards and regulations</td>
<td>31.8</td>
<td>46.1</td>
<td>69.0</td>
</tr>
<tr>
<td>Technical standards or standard setting bodies</td>
<td>34.6</td>
<td>40.2</td>
<td>86.1</td>
</tr>
<tr>
<td>Health and safety standards and regulations</td>
<td>41.3</td>
<td>47.2</td>
<td>87.5</td>
</tr>
<tr>
<td>Other public sector e.g. Business links, Government offices</td>
<td>10.5</td>
<td>38.7</td>
<td>27.1</td>
</tr>
<tr>
<td>Scientific Knowledge Base</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government research organisations</td>
<td>6.6</td>
<td>24.7</td>
<td>26.6</td>
</tr>
<tr>
<td>Private research institutes</td>
<td>7.2</td>
<td>22.9</td>
<td>31.5</td>
</tr>
<tr>
<td>Commercial laboratories or R&amp;D enterprises</td>
<td>12.2</td>
<td>28.4</td>
<td>43.0</td>
</tr>
<tr>
<td>Universities/higher education institutes</td>
<td>13.8</td>
<td>27.0</td>
<td>51.3</td>
</tr>
</tbody>
</table>

Source: CBR/IPO UK US Innovation Benchmarking Survey