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NESTA Making Innovation Flourish

Innovation Index Working Paper

Wider Conditions for Innovation

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This working paper was published as part of the Innovation Index project that NESTA is running pursuant to Recommendation 18 in the UK Government's 'Innovation Nation' white paper (March, 2008). As a consequence, it is intended to extend and provoke debate on issues related to innovation measurement. The views expressed are those of the author(s) and do not necessarily represent those of NESTA.

NESTA INNOVATION INDEX: MINI-PROJECT 3 WIDER CONDITIONS FOR INNOVATION

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EXECUTIVE SUMMARY

The aim of this paper is to suggest a conceptual framework for thinking about how to monitor the wider conditions for innovation, and to explore the selection and likely availability of indicators.

Many of the conceptualisations of the innovation process centre on the activities of the firm and its relationships, particularly with suppliers of knowledge or inputs to innovation. While setting out these approaches, we also include a description of models of diffusion of innovations to users, and a much looser encompassing conceptualisation which does not incorporate a formal model but does categorise the parts of the innovation process which are external to firms and their relationships.

We suggest taking as a starting definition of 'wideness' in wider conditions activities external to the firm (or other organisation), but including its relationships and social networks.

We recommend combining this definition of wideness with the looser conceptualisation described above. At present, there is nothing in the empirical evidence we have found which would justify the selection of one of the tighter conceptualisations, to the exclusion of other parts of the process of innovation particularly diffusion to users.

Without having been able to review exhaustively a vast literature, we conclude on the basis of the empirical literature that the following areas ought to be included in a set of indicators of wider conditions: education and skills; market structure; regulations and standards; and demand/diffusion processes. Our survey of existing data sources indicates patchy availability of the indicators which might be desired.

This report ends with a sequence of questions which could be used to narrow down the choice of wider indicators, based on a mix of empirical evidence on the importance of certain types of condition, and pragmatic decisions to make the process manageable. We would also recommend the selection of a relatively small number of sectors as construction of suitable indicators capturing the underlying complexity will be a big task. We include suggestions for next steps and timeline.

There is a substantial appendix summarising existing potential indicators, and discussing their characteristics.

1. Introduction

The process of innovation is fundamental both to economic growth and to welfare improvements not well-captured in GDP, such as either new products and greater variety, or non-market aspects of well-being. The 'great wave' of innovations of the past quarter century has revived interest in how the innovation process occurs; and the extent to which it is open to policy influence, given the varying extent to which recent innovations have affected long-term productivity growth and living standards in different economies.[1] This variation also explains why innovation features prominently in policy debates about productivity and competitiveness.

Yet innovation is sufficiently complex that although there is fairly wide agreement about the types of variables which are relevant, there is no consensus about how, exactly, it happens. Many people and institutions are involved. The relationships between them and in particular the flow of ideas and know-how will affect innovation outcomes. This means that, although innovation takes place as time unfolds, it is inherently non-linear with many possible feedback links, and these will differ from place to place depending on the economic institutions which form the environment for innovation. What's more, innovation can also be affected by deep underlying social structures (rigid hierarchies, property law) or cultural factors (the degree of conformism or fatalism in society or social attitudes to science and technology, say). In short, innovation is a multi-dimensional and endogenous process specific to its time and place.

So it is not surprising that measuring innovation as it occurs focuses on inputs to or investment in innovation and direct outcomes of this investment; this could be thought of as a reduced form approach. In this paper we address the underlying wider conditions determining the effectiveness with which the inputs deliver innovation outcomes.

There are several possible ways to approach this question, depending on how the process of innovation is conceptualised. Our aim is to set out some useful conceptual approaches, and consider their implications for measurement and for the ultimate development of the Innovation Index.

In order to avoid a scatter-gun collection of variables which are likely to facilitate innovation, some conceptualisation of the process is necessary. But there is no consensus model which makes it obvious how to order the candidate measures. The possibilities vary according to the extent to which they impose a specific model of the innovation process, and also in the extent to which they focus on wider or narrower aspects of the process.

Thus possible approaches might include:

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[1] The phrase 'great wave' comes from Gordon's review (1999).

1. A relatively loose conceptualisation which simply identifies and tracks *inputs to innovation* such as relevant human capital, existing stock of embodied technology; *capabilities to innovate* such as organisational and labour market flexibility; and *incentives to innovate* such as demand conditions, degree of competition and regulatory barriers.

2. A second approach taking a stronger concept would be a production system, shaped by the underlying technologies of production and organisation;[2] or the innovation value-chain setting out the intra-firm links in the process of innovation in such a way as to identify key spillovers;[3] or an innovation system which considers innovation in the context of the organisation of firms and supporting institutions such as universities, patent rules etc.[4] These approaches all put the spotlight on organisational and institutional forms, and on the technologies driving organisational change. They are consistent with how companies think about innovation, in terms of organisational processes and new products or services. It is largely a production-side approach to innovation, although the 'innovation system' goes somewhat wider than this.

3. A third perspective could consider conditions for innovation at different levels of social organisation: the firm, the sector, the structure of the market, institutions of governance and regulation, and social norms. In terms of possible metrics, this might add variables such as regulation, social capital, or culture. Cross-country comparisons of the diffusion of technologies – say electricity, or mobile phones – make it apparent that institutions and social conditions play an important role in influencing the use and therefore the economic and social impact of innovations.

4. Finally, it would be possible to look at the conditions for the diffusion of innovation to users, drawing on the literature on the diffusion of new technologies and/or on the role of networks.[5] There are several models of this kind; all emphasise heterogeneity of firms and consumers, and also focus on flows of information and the structure of social networks. Importantly, they consider explicitly the role of demand as well as supply ie the *use* of innovations as well as their creation. This contrasts with many discussions of innovation which consider only the supply side.

Furthermore, the choice of approach and indicators should also be informed by objective selection criteria. We address what these might be and what further work would be necessary to develop these criteria.

[2] as in for example Best 2001;
[3] see eg Roper, Du & Love 2006,
[4] as in Baumol 2002
[5] eg Barabasi 2002, David 2003, Ormerod 1998.

2. Structure of this report

In the next section we set out a number possible approaches to understanding the wider conditions for innovation, reviewing where relevant existing literature; we focus on terminology and which agents are engaged in which innovation activities; and on the relevant concept of 'wideness'. The aim is to clarify the issues rather than provide a comprehensive review of a voluminous literature. Section 4 then turns to an assessment of the strengths and weaknesses of potential indicators in each case, including overlaps between the different conceptualisations in terms of indicators. In section 5 we address the question of empirical evidence on the relative importance of different indicators as a prelude to selecting the best approach – and, to anticipate, find that there is less than we might wish to inform Nesta's choices. We consider whether some empirical research could sensibly be commissioned. Section 6 concludes by setting out the issues monitoring the wider conditions for innovation, and the strengths and weaknesses of alternative approaches. Section 7 ends with our recommendations for how this work should be taken forward.

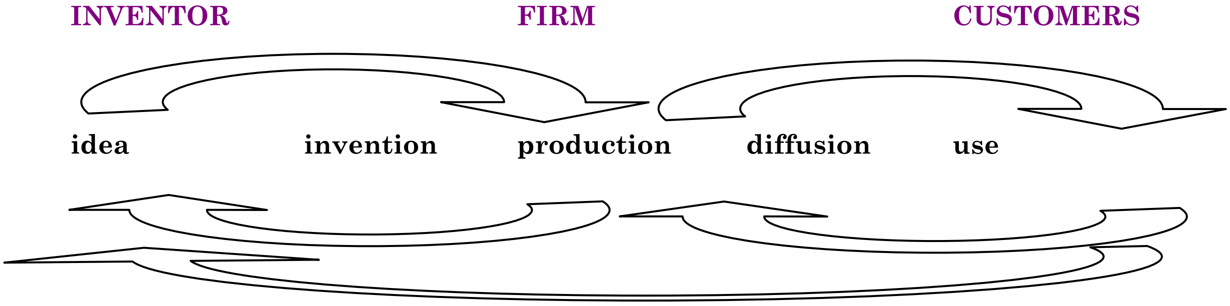
3. Concepts

How can we bring some order to the development of indicators for assessing various potential measures of wider conditions when there is no single, obvious conceptual framework? First we consider some high-level analyses and fit them into a typology of the activities which make up the innovation process. This sets the framework for the rest of the report.

Models of innovation

Figure 1 sets out the agents and activities in the innovation process, as it occurs through time. The roles are gathered under the umbrella titles of inventor, firm and user; and their related activities are designated in the diagram. The arrows indicating the relationships between these agents are at least as important; they encompass the two-way flows of ideas and information which are arguably at the heart of innovation. These also have their designated terms.

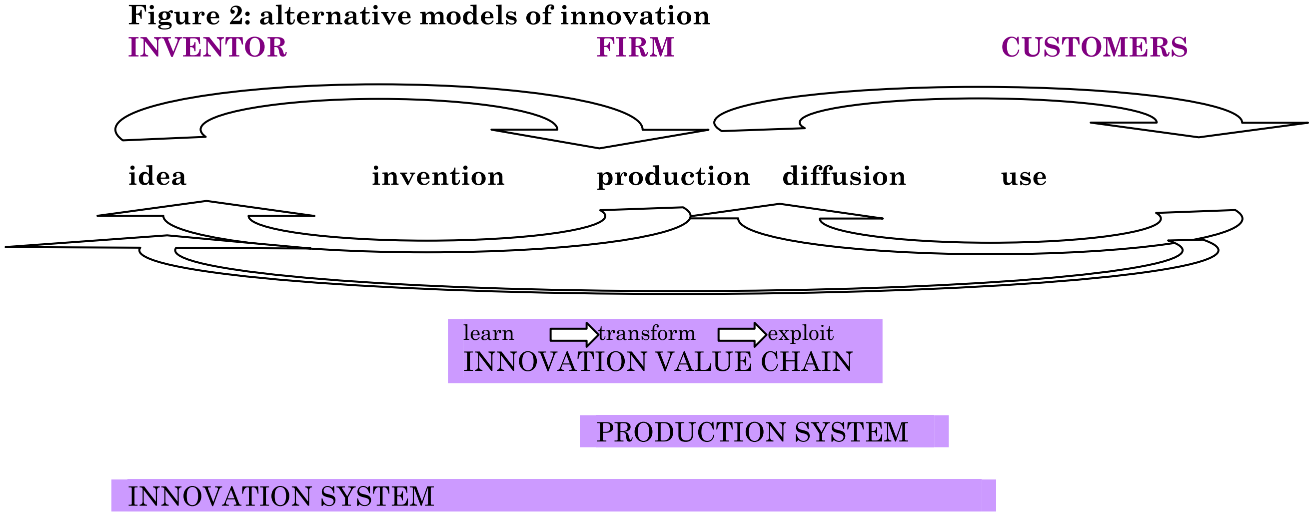
Figure 1: the process of innovation



It should be noted that this description of the process concerns a representative firm. In reality the most sensible unit of analysis is the industry or sector; while some aggregation is needed for manageability, aggregation of the process to the level of the entire economy does not make much sense when it comes to considering the nature of networks and feedbacks, for example. However, most of the existing indicators, discussed below, are presented at the level of the whole economy.

We can map onto these basic roles and relationships some of the alternative conceptualisations which have been offered in the literature. Different authors have focussed on specific roles and links, mainly centring on the firm (although it should be noted that other types of organisation could be considered, such as public or social sector agencies). These approaches, and the parts of the innovation process which they describe, are shown in figure 2.

Figure 2: alternative models of innovation



Taking these labels in figure 2 from top to bottom, the first framework is the *innovation value chain.* This is the "recursive process through which firms source the knowledge they need to undertake innovation, transform this knowledge into new products and processes and then exploit their innovations to generate added value."[6] It covers the role played by the firm but also includes the upstream links which provide knowledge and the downstream links which result in the commercial revenues from selling products and services. These incorporate the market intelligence and incentives which affect the commercial return to innovation. The 'transform' link in the chain occurs within the firm. A strength of this approach is its emphasis on processes and organisation within the firm, which have been found in empirical studies by other researchers to be an important contributory factor to productivity.[7] The 'learn' and 'exploit' links involve parts of the innovation process outside the firm.

[6] Roper, Du and Love (2006) p1.
[7] Brynjolfsson et al (2000)

Moving down in figure 2, the next concept introduced is the *production system*. This emphasises even more strongly organisational and management aspects of innovation, and not only in a single firm but specifically at the level of all the firms operating in an industry or sector. While it pays little attention to upstream sources of inventions and knowledge, it illuminates relationships and knowledge-transfer amongst firms, and the incentives which arise from the structure of the market. The optimal organisation of the firm, from the perspective of increasing productivity growth, will differ depending on the underlying technologies available. So an analysis in terms of production systems emphasises the productivity gains in a cheap information era in moving from hierarchical, vertically-integrated corporations with 'hub and spoke' information flows to flatter networks of organisations (including suppliers and partners) with greater outsourcing. This means that in this type of industry structure, inter-operability and standards become more important.[8] However, the focus is on the capabilities of firms – specifically business organization, production capabilities and employee skills – rather than other roles in the innovation process.

The third possible conceptualisation in this figure is Baumol's 'innovation machine' or the similar concept of the *innovation system*.[9] This sees innovation as an endogenous process of knowledge generation and knowledge transfer involving many roles and many institutions in the economy. Baumol distinguishes between small entrepreneurial firms which are close to the point of invention and introduce radically new products or services; and large oligopilistic firms which routinize innovative activities and introduce many important but incremental changes in products and services, using this as their prime competitive weapon. This is a simplification – some large firms do generate step-change innovations and some small firms stick to incremental improvements – but it is a useful one. In each case, innovative activities depend on a wider set of conditions, notably: effective competition policy; the enforcement of contracts and protection of IP; the economy's knowledge base especially in universities. The first two of these need to be such as to encourage firms to share knowledge with each other through the licensing or other dissemination of innovations.[10] Extensions of Chris Freeman's concept of an innovation system place less emphasis on firm and industry structure, and more on the backward linkages between knowledge generators and the firm. We include the two together because they do, broadly speaking, cover the same sets of roles and linkages.

Models of diffusion

All of these are well known models, but there is a further type of model we believe is particularly relevant to a discussion of wider conditions for

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[8] Best 2001, Coyle 2003.
[9] Freeman 1995
[10] Baumol 2002.

innovation, namely those which focus on the process of diffusion of an innovation amongst firms and users, feedback amongst firms, adaptations by users, and feedback from users to firms. This list bundles together a number of important distinct elements; and indeed there are several different ways of modelling the diffusion and use aspects of the innovation process. Paul David introduces a model of innovation diffusion with heterogeneity amongst firms and users, in which case the existence of any fixed costs in adopting an innovation – including the costs of reorganising production – mean there will be a minimum scale below which introducing an innovation is not profitable, and diffusion will be slow, with productivity impacts even slower. In addition, feedback from early adopters will modify the innovation and reduce real costs; this endogenous process makes expectations amongst users of the ultimate market size an important determinant of the speed of diffusion.[11] In his historical work, David has also strongly emphasised the importance of complementary investments, including social investments (such as the generation network in the electrification of industry), consistent with Brynjolfsson.[12]

An alternative is to consider the networks of personal or mediated contacts along which information flows in the diffusion process. There is a marketing literature which addresses the sale of innovations to customers. More relevant to us here are network models such as those presented in Barabasi and discussed in economic applications by Ormerod. "Small worlds" and scale-free networks are likely to be particularly relevant in innovative industries, where typically there will be a few larger companies acting as hubs in the network, with many other firms and suppliers linked to them. A growing number of industries can almost certainly be characterised in this way as the dis-integration of global supply chains during the past quarter century has made networks of allied firms commonplace.[13] A related literature looks at 'information cascades' whereby consumers learn about new products and services.[14]

There is also a recent literature on collaborative or open innovation.[15] This is concerned more with the reverse segment of the feedback loop shown in figure 1. While customer feedback has long been recognised as an important process whereby recent innovations are modified by users often to the surprise of their producers – the telephone is one example, originally expected to be used as a broadcast device similar to what was later invented in the shape of a radio – the recent literature includes feedback *between* users of an innovation, without mediation from a producer which controls the subsequent output; well-known examples are

[11] David 1969, 2003.
[12] David 1991
[13] Barábasi 2002, chapter 14; Ormerod 1998 for other applications. A small world network has a small number of hubs with many links to them, such that most nodes in the network are linked by very few steps. Scale-free networks are those which follow power laws, generating the familiar 80:20 rule of thumb.
[14] See for example Bikhchanddani et al 1998.
[15] See eg Tapscott 2007, Nesta 2008.

Wikipedia and Linux. Users are thereby incorporated into the production process, and the distinction between production and consumption becomes uninteresting.

Do we need models?

So far we have introduced a range of analytical approaches which differ in their focus with regard to different parts of the entire scope of the innovation process. It is worth asking, finally, if any individual framework is necessary: is it not less restrictive simply to list candidate indicators of wider conditions without imposing much analytical structure at all? This somewhat downplays the importance of the links between different roles, as they figure as one item on the list of candidates, but on the other hand imposes no constraints on the analytical structure. What would be lost by opting for a loose portmanteau of indicators? It would be possible to simply list potential indicators without any analytical framework at all, if some criterion for selection could be developed. Figure 3 demonstrates this approach, again mapped onto the stages of the process set out earlier.

Figure 3: a loose conceptualisation

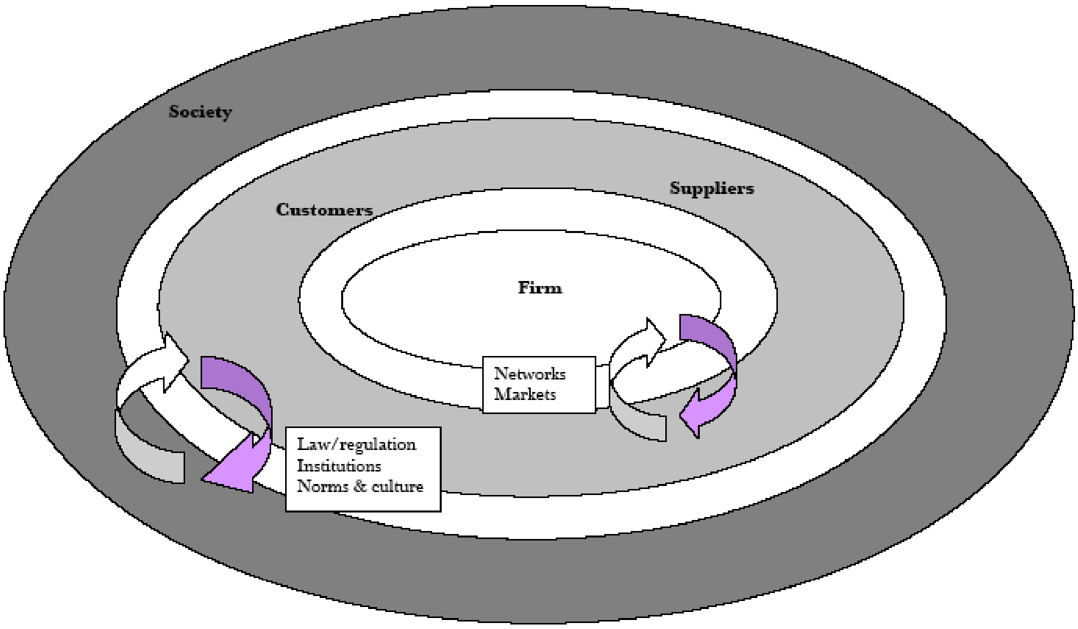
Ideas	Invention	Production	Diffusion	Use
Inputs to		Capabilities to	Incentives to	
• Science & knowledge base/universities • Education & skills • Regulation of discovery (eg scientific/medical licenses, ethics bodies) • Culture and social norms	• Patent law • R&D links • Knowledge networks (incl. supply chain) • Entrepreneurship	• Corporate R&D • Employees' skills • Management quality • Organisational flexibility • Regulation of the firm • Ability to make complementary investments	• Patent law • Market structure • Regulation of the market (inc. openness to trade) • Standards • Infrastructure /access to market • Marketing/media	• Complementary infrastructure/goods • Macroeconomic context • Culture & social norms • Education • Social networks

'Wideness'

We return below to criteria for the selection of indicators. However, we end this section with a discussion of the concept of 'wideness'. Figure 4 below envisions innovation as a social process; it centres on the firm (or other organisation) as the single most important entity in the process which turns new ideas into economy-wide productivity improvements. The middle ring represents other organisations and individuals linked directly to the firm as suppliers or customers, while the outer ring represents economic institutions, government and other social structures. The figure also shows the two way informational and social links between each orbit. Not shown are links amongst firms which can also be vital for transmitting information, and similarly, links amongst customers. The figure also clearly simplifies by omitting direct links between firms and wider institutions, some of which in some sectors may be vital to innovation, such as direct relationships between universities and firms – this is for visual clarity only, and one could designate the university in this example as a 'supplier'.

The point of this figure is not to capture the whole richness and complexity of the process in one diagram, but rather to flag up the distinction between variables affecting the performance of the firm which are directly relevant to the innovation process, and those which pertain to 'wider conditions'. Distance from the central innovative activities of firms seems a sensible starting point for the idea of wideness.

Figure 4: making sense of 'wider'



This above discussion of concepts leads us on to the next two questions: how much might possible indicators of wider conditions overlap between the different approaches set out in figure 1? And what objective criteria – including empirical evidence of importance to the innovation process – do we have for making a choice? We address these in the next two sections.

4. Potential Indicators

Over time there has been an evolution in the types of indicators of innovation collected (set out in figure 5 below) which broadly speaking tracks the conceptual pathway set out above. Whereas researchers some decades ago measured only inputs used by firms in innovating, the most recent work on indicators has been more systemic and included some concepts – such as networks or organisational metrics – which are more relevant to wider conditions for innovation.

Figure 5: evolution of indicators of innovation

1st Generation **Input Indicators (1950s-60s)**	***2nd Generation*** **Output Indicators (1970s-80s)**	***3rd Generation*** **Innovation Indicators (1990s)**	***4th Generation*** **Process Indicators (2000s)**
R&D expenditure S&T personnel Capital Tech intensity	Patents Bibliometrics Products Quality change	Innovation surveys Indexing Benchmarking Human resources ICT indicators	Knowledge Intangibles Networks Demand Clusters Management techniques Risk/return System dynamics

Adapted from Milbers [16] and Sirilli[17]

Thus the first generation of STI indicators reflected a linear conception of innovation, omitting any feedbacks, and focused primarily on direct inputs to the production process at an aggregate level, such as R&D investment, education expenditure, capital expenditure, research personnel, university graduates, technological intensity and so on.

The second generation complemented input indicators by taking into account intermediate outputs of science and technology activities, such as patent counts, scientific publications, counts of new products and processes and high-tech trade. These began to cover some of the linkages set out above.

The third generation focused on a fuller set of innovation indicators and indices based on international data comparisons and incorporating service sector innovations in the new surveys. They also focussed more closely on ICTs, which had clearly become the most interesting and important source of innovation.

Indicator development and classification now is beginning to take a more systemic approach as a way of capturing the dynamics of change. The

[16] 'Innovation Metrics: Measurement to Insight,' prepared for National Innovation Initiative, prepared by Egils Milbers, Center for Accelerating Innovation and Prof. Nicholas Vonortas, George Washington University.
[17] Giorgio Sirilli, 'Developing science and technology indicators at the OECD: the NESTI network,' National Research Council of Italy

actors in the system, be they firms, universities or public institutions engage in activities that are linked to other actors and activities. Examples of such linkages are contracts, cooperation agreements, co-publishing, commercialisation of intellectual property and flows of knowledge and capacities through the movement of people. Understanding the system requires a new generation of indicators – far more than aggregate statistics produced at regular time intervals. It requires micro-data relating to the actors available for analysis. By following the behaviour of actors over time it would be possible to study causal relationships rather than correlations of characteristics from aggregate cross-sectional data. However, in the latest generation of indicators these are at an early stage of development and at present lack the full richness that would be desirable in the following:

- Knowledge indicators: accounting for the knowledge that underlies the creation of innovations, particularly the ways in which it is developed and diffused, as opposed to well-known indicators of knowledge production such as patents. It is likely that this concept can only be captured by composite indicators, including knowledge investment and composite performance indicators.
- Networks: again likely to be captured through composite network indicators accounting for both contractual agreements like strategic partnerships, intellectual property licensing and for informal collaboration and knowledge exchange such as working relationships of individuals across organisations (clusters). Networks may be regional, national or global.
- Conditions for innovation: indicators that both describe the main characteristics of the innovation system and its dynamics and look forward in anticipation of likely broad developments (e.g. mapping of general purpose technologies, monitoring demand shifts and global innovation patterns, technology accounting).

At the present time, to the extent that these 4th generation metrics exist at all, they remain ad hoc. However, building indicators takes a very long time; between the conception of a new indicator, the development of a measuring system, data collection, and analysis of the results, it may take decades.

Meanwhile, innovation surveys are playing a central role in innovation indicator data gathering. They are designed to assist policy-makers in benchmarking a country's innovative performance and to give researchers a better understanding of innovation processes. However, there are several questions with regard to their utility:

- Do they in fact provide the information required to understand innovation processes? For example, do they provide adequate information to analyse industrial and regional clusters? What should the unit of analysis be: the firm, the innovation or the innovating network?

- For many years, innovation surveys were more concerned about measuring inputs and outputs of innovation occurring within a particular firm, rather than at the processes – the dynamic relationships that influence innovation.

- Salazar and Holbrook[18] believe important areas are not adequately covered by any innovation surveys including: the diffusion of new technologies, as opposed to their creation; linkages between the firms and other agents of the innovation system (although there are some limited indicators of co-production of knowledge, such as co-authorship); and lifelong training and learning. They conclude that the past decade of survey experience has not resulted in unified methodologies or procedures to collect data.

Innovation surveys have mainly focused on the supply side of policies, emphasising innovation inputs such as activities and expenditures. But policies supporting linkages, networks and collaboration among actors are largely omitted, although awareness of these gaps has meant that innovation surveys are moving in that direction. Over the past 10 years, some work has been done with process indicators (describing knowledge flows or research networks) and micro-level indicators – monitoring the behaviour and performance of key actors such as firms or universities. Since these pilot studies were conducted on an ad hoc basis, they have yet to produce internationally comparable data or methodologies.

Meanwhile, due to this lack of diffusion indicators, the EIS provides one of the only means of describing innovation as a creative activity.[19] A primary characteristic of creative destruction is the continual entry of new firms and the exit of established firms that no longer provide competitive advantage – commonly known as 'churn'. New firm formation is part of entrepreneurship, though exit is often dependent on the regulatory environment. The EIS for 2008-2010 does provide an indicator of 'firm renewal' although just for SMEs.

The least represented area in innovation indicators is that of industry-science links. This is especially troubling as it is one of the particular deficiencies of EU innovative capacity.[20] Indicators are needed with regard to cooperation, co-patenting and co-publishing between firms and research institutes, researcher mobility between industry and science,

[18] Salazar and Holbrook, A debate on innovation surveys, Science and Public Policy, August 2004.

[19] Carauannis, Elias G., 'Past, Present and emerging innovation metrics and indicators: public and private sector perspectives,' Presented to the Innovation Vital Signs Workshop, April 2007.
[20] OECD, 'Developments in EU Statistics on Science, Technology and Innovation, 2007.

private funding of basic research, patenting by universities and public research institutes and university spin-offs. Though several projects have attempted to gather data on spin-offs from universities and research institutes (OECD 2003, PROTON study, Conesa et al 2004 and ASTP in 2006), this is an area which needs the collection of annual, high quality statistics. Any survey of TTOs (technology transfer offices) serving universities and public research institutes should be conducted at the European level because with only about 1,000 universities in Europe, the target population is not large enough to be efficiently surveyed at the national level. A centralised European survey would avoid problems associated with national differences in survey design and methodology that affected the OECD study. Such a survey could also provide another indicator for the commercialisation of publicly-funded research.

It has been recommended that NESTI, the OECD's National Experts on Science and Technology Indicators, undertake a multi-year program in conjunction with business, academic and government experts, to develop new methodologies, indicators and other analytical tools for measuring and assessing (amongst other things) IPRs and linkages between them and innovation and economic performance. Tools are needed to measure the role of IPRs as a source of information and an enabling mechanism for technology transfers and the development of technology markets. The OECD Experts Workshop also recommends that the OECD undertake more empirical studies about IPRs, innovation and economic performance.

Another significant gap in current indicators is in the area of economic incentives and institutional regimes. Regulatory barriers, openness to national and international competition, ease of entry and effective protection of intellectual property need to be assessed as they form the wider conditions in which firms operate and affect the probability of commercialising innovations successfully.

Finally, there has been some activity in the area of innovation indicators in other countries which is worth noting, in particular:

Canada

The Innovation Systems Research Network (ISRN): a collaborative initiative to undertake and disseminate research results concerning the diverse nature of regional and local innovation systems across the country. The objectives of the program are to:

- Encourage creation of links and the exchange of ideas and information among the academic community, private sector firms and associations and policy makers, leading to a better understanding of the nature of innovation in Canada
- Develop agendas for research on the relationship among innovation, the knowledge-based economy and regional economic clusters

- Foster a multidisciplinary approach to the research that includes fields such as business, economics, urban planning, public administration, and science and technology management
- Encourage the development of graduate students with interests and skills necessary for contributing to future research in this area and/or practicing as managers of science-based innovation
- Improve innovation systems and strengthen Canadian competitiveness by influencing public policy and corporate strategy.

United States

- The US Small Business Innovation Research Program (SBIR). This is aimed at increasing the role of small firms in federally supported R&D. Federal agencies set aside a fixed percentage of R&D budgets for this purpose and its possible to look at SBIR expenditures. Research has shown that some of the growth in tech-based industries has had its origins in government-funded research and support. Phases of SBIR are 1: grants to assess scientific and technical merit, 2: grants develop the idea further and 3: the innovation must be brought to market with private sector investment.
- Also in US are CRADAs: Cooperative Research and Development Agreements, measures of federal laboratory-industry collaboration, technology transfer and partnerships.

New Zealand

Also appear to be doing interesting monitoring and analysis.[21]

This has been a sketch of some shortcomings in the available data. The Appendix sets out a matrix of potential indicators mapped on to the loosest conceptual structure set out earlier. It includes a brief description and discussion of the candidate indicators, as well as giving sources. There are several points we have concluded from this exercise in assessing the potential availability of indicators of wider conditions for innovation.

- Although a loose 'portmanteau' approach might at first glance seem attractive in not imposing constraints, it quickly results in a flood of potential indicators – all the more so if sub-divisions such as different sectors or regions are to be included. What seems at first like a restrictive approach is probably necessary for manageability.

[21] Innovation New Zealand: Growth and innovation indicator approach: http://www.med.govt.nz/templates/MultipageDocumentPage____1870.aspx#P80_13769 http://www.stats.govt.nz/NR/rdonlyres/4D070B56-8EFB-4DFD-A351-3C145AC7B51C/0/5511SNZinnovationreportffweb.pdf

- As prefigured in the discussion above, many of these potential indicators are not satisfactory in their current form. They may be one-offs, infrequently gathered, vary little over time or geography of analysis. Many are collected in surveys subject to all the difficulties listed above.

- Most of the potential conditions we might be interested in are complex and multidimensional ideas. Constructing a summary indicator will be fraught with difficulty. One example is regulation. Some forms of regulation will act as a barrier to innovation, say restrictions on the use of genetic material, or product safety requirements for one type of material which happen to prevent the (safe) use of another material. Other forms of regulation such as standard-setting can greatly increase the incentive to innovate by increasing the size of the addressable market or reducing uncertainty. Another example is the protection of intellectual property rights, where it is widely appreciated that there is a trade-off between the return to the inventor who gains a temporary monopoly through a patent and the wider diffusion of the invention. Should an indicator privilege the incentive to innovate and the future stream of inventions, or the welfare gain from the widespread diffusion of innovations? How should account be taken of the frequent licensing of patents? Under almost every heading, similarly difficult questions arise.

In the next section we turn to a final set of issues, concerning the evidence we have on the empirical importance of different types of indicators, before proposing a way forward.

5. Evidence

The final question we address is whether or not there is any empirical evidence on the importance of different types of conditions for innovation. In the short timescale for this report, we have identified some clear evidence on the importance of four categories of indicator.

Education and skills

It is immediately obvious that education and skills are in a direct way linked to innovation, especially for 'high-tech' forms of innovation. Thus for information technology or pharmaceuticals, for instance, the level of availability of relevant scientific and technical skills will clearly be important. More broadly, the voluminous recent literature on economic growth, post-dating the introduction of models of endogenous growth, shows a very important role empirically for the economy's general level of human capital in subsequent growth.[22] Indeed, in all of the many studies

[22] See Barro 1997 for an influential survey.

of the empirics of growth, human capital is more or less the only consistently significant explanator, and education is therefore of strong relevance to the innovation process.

The organisation of production

As referred to in sections 2 and 3, a number of studies find that investment in organisational change has been much more significant than physical investment in firms where innovation has resulted in productivity gains. These recent studies on information and communications technologies are entirely consistent with many historical and managerial studies of innovation, which highlight the importance of complementary innovation in management, organisation and production processes.[23]

Market institutions

Two aspects of market organisation are empirically relevant for innovation. The first is the degree of competition, the second the nature of regulation particularly in network markets and technological markets. On the question of *competitive structure*, there is a long debate in the literature about incentives to innovate in competitive versus monopolistic markets. There is a theoretical presumption dating at least back to Arrow that competition is the principal incentive to innovate; and an alternative theoretical presumption that innovation will increase with monopoly due to the increased return delivered by market power.[24] The weight of evidence is that competition drives innovation, although Aghion et al find evidence of an inverted U-shaped relationship between innovation and degree of competition.[25] The literature on network industries emphasises the threat of competitive entry rather than the number of firms in an industry at any given time. In terms of *regulation*, it is prima facie clear that inappropriate regulation will act as a barrier to innovation – or as a stimulus to innovations which avoid the barriers. Furthermore, regulation in the form of standard-setting can be an important stimulus to innovation by increasing the ultimate size of the market, or at least reducing uncertainty about the size of the future market. This is often discussed in industries such as telecommunications, but there are many examples – one neat illustration is the innovation of containerisation in shipping.[26]

Demand and the diffusion of innovations

Finally, innovations succeed, and create value, when they are bought and used. There has been relatively little attention paid, at least by economists, to the 'demand pull' aspect of innovation. Rosenberg noted long ago that diffusion rates vary widely between innovations, with the variation amplified by the importance of feedbacks. In a survey article

[23] See for example, Geroski 2003; Mokyr 2002.; Rosenberg 1994; and a number of chapters in Stoneman 1995.
[24] Arrow 1962. Blundell et al 1999 found more innovation under monopoly in British manufacturing.
[25] See Geroski, Geroski and Pomeroy, 1990; Aghion et al 2002.
[26] See Levinson 2007.

Hall notes that factors affecting adoption of innovations by users are: the relative benefit of the innovation compared to existing substitutes; its compatibility with existing conventions and social norms; the complexity of the innovation; its trialability by customers; the ease of evaluation of benefits in use; and uncertainty about the ultimate scope of network and other benefits in use. However, as she notes, there is little systematic data on diffusion or empirical evidence on the importance of the different factors listed here.[27] Having said that, diffusion is clearly fundamental to the impact of innovation.

Other links and relationships
Diffusion to users forms the one aspect of the many links and relationships involved in the entire innovation process for which there exists any empirical evidence, notwithstanding Hall's observations about the paucity of data. While there are literatures looking at the operation of knowledge networks, university-business links and so on, they tend to look at effectiveness of the relationships on the assumption that the outcome will be empirically important for innovation. This seems an unarguable presumption, but we are not aware of any evidence on the potential scale of the impact.

It is apparent from the discussion in this section that the empirical literature is patchy, with much of the evidence available in the management rather than economics literature. It is not possible to draw from the literature a systematic comparison of the importance of one type of condition for (or indicator of) innovation rather than another. So in assessing the impact of innovations in ICTs in terms of productivity or growth, it is not possible to conclude that the reorganisation of work processes, say, has been more or less important than the availability of human capital skills to operate the new technologies, or the social networks operating within the computer industry, or the setting of standards such as internet protocols or GSM. This might seem a negative conclusion but it is an important one in terms of the selection of wider conditions for monitoring. It is to selection criteria that we turn next.

6. Selection criteria

We hope this paper has helped apply some analytical structure to the vast array of potential indicators of wider conditions for innovation. In our view, the plethora of available conceptualisations is a reflection of the reality that the process of innovation is inherently social, non-linear and complex. This makes the wide concept of the innovation system, augmented by an emphasis on diffusion to users, very appealing, and indeed natural in the context of thinking about the wider conditions for innovation; the narrower conceptualisations focus mainly on what occurs within and close to the firm.

[27] Rosenberg 1982, Hall 2004.

However, the discussion here has made it clear that it is a large task with no obvious innate selection criteria to choose a manageable number of relevant indicators for future monitoring.

We therefore propose selection via the following sequence of questions, some analytical or empirical, some simply pragmatic:

1. What do we mean by 'wider'?

    We suggest using the concept of wideness illustrated by figure 2, ie. outside the firm and distant from the immediate production process. This excludes indicators of management and organisational change from an assessment of wider conditions, for instance. But it would not necessarily exclude the relationships between firms and their users or between firms and their sources of knowledge and ideas.

2. Is there an empirical literature confirming the importance of the proposed condition/indicator for innovation?

    Our review of the literature in the scope of this project has been extremely brief. We suggest a more thorough review of the evidence, which will in turn inform the construction of measurable indicators of wider condition (see 5 below).

3. Is the proposed condition/indicator not being monitored elsewhere in the innovation index?

    This is a matter of common sense. It has the practical implication that – taken along with our first selection criterion – the indicators of wider conditions chosen will probably end up focussing on the diffusion and use end of the innovation process, as these are least likely to be covered elsewhere. However, we would recommend the inclusion on the basis of this criterion of indicators of the two-way links between firms and innovators, and between firms and customers, as part of the way 'wider' should be understood, unless this would be pure duplication of effort elsewhere. As section 2 made clear, the most common conceptualisations of innovation are those centred on the firm. Section 4 showed that the vast majority of existing indicators of innovation cover the inputs and the capabilities of firms.

4. Is the proposed condition amenable to policy action?

    We would argue there is little merit in this kind of exercise in monitoring conditions which are clearly important but which cannot be altered on any reasonable timescale. Examples might include many cultural and social norms. However, this is a judgement call – others might argue that policy can affect cultural attitudes such as attitudes to entrepreneurship, or genetically modified foods, or smoking, and so the evolution of norms would be worth monitoring.

5. Is it practicable to construct an indicator (or set of indicators) which adequately captures the complexities of the way the underlying condition affects innovation and for which statistics will be available on a timely basis?

    This is another pragmatic criterion which can help the choice between potential indicators at a later stage in the process.

We believe a selection process will be necessary – a complete portmanteau approach would be unrestrictive but unwieldy. Our review of existing indicators, covered in section 4 and the appendix, leads us to believe that there will be an overwhelming number of imperfect indicators of wider conditions which will be of varying relevance to each of the stronger analytical frameworks set out earlier, in particular to the forward linkages from firms through markets and other institutions to end-users. We have set up the data appendix in the shape of the least restrictive conceptualisation, which combined with a focus on 'wider' as meaning outside the firm, is consistent with what we learned about the existing empirical evidence and imposes a minimum amount of structure. Our recommendation would be to select a relatively small number of indicators and concentrate resources on their careful design and construction. This would deliver a more informative set of empirically relevant indicators of conditions not being assessed elsewhere.

7. The path forward

In conclusion, then, we propose the following steps:

1. A systematic review of the relevant literatures on the following areas:
    a. The impact of market structure and competition on innovation
    b. The impact of regulation and standards
    c. Diffusion of innovations
    d. Linkages from firms to innovators on the one hand and customers on the other.
    e. The relative importance of the different stages in the innovation process set out in figure 1, with a view to understanding the most appropriate conceptual framework and the importance of wider conditions relative to actions by firms themselves.

    Each of these is a very large literature and it was beyond our scope in this project to be comprehensive. The outputs would offer both an empirical assessment of importance and also insight into how to construct specific indicators.

2. The selection of a manageably small number of potential indicators using the sequence of questions set out in section 6, and the background information we have provided here in section 4 and the appendix.

3. The selection of a number of sectors or technologies of greatest interest, a selection which should itself be empirically determined by either the importance of the sector to the economy and living standards (eg finance, public sector), or the importance of innovation to the sector (eg creative industries, pharmaceuticals).

4. The design and construction of a set of indicators of wider conditions, interacting in particular with any new or revised surveys which might be commissioned. This step is clearly the majority of the effort required.

A feasible timeline for this work would be:

Months	1	2	3	4	5	6	7	8	9	10
Review of evidence										
Selection of indicators										
Design and construction of pilot indicators										

This work could be carried out by a small team with relevant knowledge and experience. The bulk of the work lies in the third element which, like all data-intensive exercises, would involve a lot of work. Further cost, although mostly ongoing and beyond this timeline, would lie in the potential addition of questions concerning networks and diffusion to surveys, as these are the areas least well covered in existing data and surveys. We think – subject to significant uncertainties about the nature of the teams which might be interested in this work and the possibility of economies of scale and scope with other projects – that the total cost for the development of indicators of wider conditions might be up to £100,000.

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APPENDIX

This appendix describes the availability for different potential indicators of wider conditions for innovation using the 'loosest' conceptualisation set out in the report. Taking wideness to be a measure of distance from the activities of the firm would make the indicators in the central column here less relevant but they are included for completeness. For convenience, the relevant figure (figure 3) is repeated here.

Ideas **Invention** **Production** **Diffusion** **Use**

Inputs to | Capabilities to | Incentives to

• Science & knowledge base/universities • Education & skills • Regulation of discovery (eg scientific/medical licenses, ethics bodies) • Culture and social norms	• Patent law • R&D links • Knowledge networks (incl. supply chain) • Entrepreneurship	• Corporate R&D • Employees' skills • Management quality • Organisational flexibility • Regulation of the firm • Ability to make complementary investments	• Patent law • Market structure • Regulation of the market (inc. openness to trade) • Standards • Infrastructure /access to market • Marketing/media	• Complementary infrastructure/goods • Macroeconomic context • Culture & social norms • Education • Social networks

A discussion follows the summary table, which reveals the varying degree to which potential indicators already exist; there is a strong bias towards coverage of invention in the existing data, and relatively little on diffusion and use.

Inputs/ideas	Inputs/invention	Capabilities/Production	Incentives/diffusion	Incentives/use
Science base/universities Knowledge transfer indicators from HE-BCI Survey Indicators of commercial exploitation by UK HEIs PROTON study: survey of European spin-offs from universities and public research institutes Bibliometrics (Thomson ISI) Public spending on science: real growth, yearly DIUS. Milken Institute Indices: • Biotech Patent Composite Index • University Technology Transfer and Commercialisation Index • University Innovation Pipeline (intl. Bibliometrics)	**Patent Law** World share in triadic patent families, EPO, UKIPO Patent applications per head of population PATSTAT: new worldwide patent database	**Corporate R&D** BERD, MA14, ONS Business Monitor provides detailed breakdowns by product group and region of business R&D expenditure and funding. R&D Scoreboards (including R&D financed from abroad) Real R&D intensity Access to finance: Milken Institute Capital Access Index. Business angels	**Patent law** Intellectual Property Rights as indicators for innovation, NIND Policy Relevant Nordic Innovation Indicators, March 2008, uses data from EPO	**Complementary infrastructure** General and ICT infrastructure: OECD, World Bank • Quality of general infrastructure • Quality of national transport network • Quality of air transport • Fixed line penetration • Mobile penetration • Internet penetration • PC penetration • Intl bandwidth • ICT expenditure • Mobile price basket
Education and skills STEM skills: monitoring by HEFCE 2006 Programme for Intl Student Assessment (PISA) SET Fair report	**R&D Links** Extramural R&D, UKIS Total R&D as % of GDP, OECD MSTI international. EIS: UK innovation leader Total R&D expenditure by	**Employees' skills** Investment in training: UKIS Active population participation in lifelong learning, Eurostat Labour Force Survey.	**Market structure** No simple relationship and no obviously available indicators, though there are studies. Market structure and innovation are simultaneously shaped by market characteristics, technology, demand, institutional framework, strategic interaction	**Macroeconomic context** IMF World Economic Outlook OECD Economic Outlook OECD in Figures OECD Factbook

Leitch Review of skills 2006 • Apprenticeships • Participation in higher education	affiliates of foreign companies Intl comparison of R&D intensity, R&D Scoreboard R&D by selected product groups, ONS 2008		and chance.	STI Scoreboard
Regulation of discovery DIUS and BERR endeavouring to identify how regulation may promote or hinder innovation.	**Knowledge networks** % of innovative firms developing innovations through collaboration: CIS4 role played by design and creative industries: CIS4 Creativity Index Collaboration between Technology Strategy Board, RDAs and Das Methods of protecting innovation: • Confidentiality agreements • Lead time advantage on competitors • Secrecy • Trademarks • Complexity of design • Copyright • Registration of design • Patents Source: UKIS Innovative SMEs cooperating with others (% of total number of SMEs): CIS Importance of info sources for innovative enterprises: UKIS • Own enterprise • Suppliers • Customers • Competitors	**Management quality** Training of managers in selected countries: • Avg terminal education age • Graduate % • Off-the-job training • On-the-job training Work Foundation CEP/McKinsey study of management practices in mfg. Mgmt practices scoring correlates to a range of metrics including labour productivity, sales growth and capital employed. Knowledge Management (KM) practices indicators: OECD KM Survey. Survey of mgmt practices and impacts on innovation in New Zealand, OECD.	**Regulation of the market** Ease of doing business indicators: • overall ease of doing business • starting a business • dealing with licences • empl workers • registering property • getting credit • protecting investors • paying taxes • trading across borders • enforcing contracts • closing a business Source: World Bank, available for most countries, annually. UK FDI: OECD and business R&D funded from overseas. Exposure to intl competition: UKIS 2007, DIUS Indicators of regulation in energy, transport and communications (ETCR) OECD. Indicators of product market regulation (PMR) OECD	**Culture and social norms** Public readiness for innovation: Eurobarometer Innobarometer: provides measure of innovation demand based on a survey of 30,000 Europeans. Public Attitudes to Science 2008 A Survey, DIUS. Some intl comparisons available with use of Eurobarometer and research by the National Science Foundation. Comparisons available with surveys in 2000 and 2005.

	• Consultants or private labs • Universities or other HEIs • Govt or public research institutes • Industry conferences or fairs • Scientific or trade publications • Trade associations • Technical, industry or service standards Patterns of intl collaboration for the UK and leading partners: • Total research output & collaboration • Changing volume of intl collaboration			
Culture and social norms DIUS/Research Councils UK Public Attitudes to Science Survey 2008. Sciencewise Expert Resource Centre (ERC) funded by DIUS and launched in May 2008 as a tool for helping ministers and officials understand public views and concerns on complex and controversial scientific issues. IIIP Innovation Confidence Index: Work by Richard Florida: Euro-creativity Index (includes Technology index, talent index and tolerance index) 'Europe in the Creative Age,' Feb 2004.	**Entrepreneurship** New firm formation, enterprise churn, GEM GEM: main measures: • Entrepreneurial activity prevalence rates • Characteristics of early-stage entrepreneurial activity • Entrepreneurship perceptions EU Benchmarking Enterprise Scoreboard (attempt to link innovation with performance) OECD Entrepreneurship Indicators Project Danish consortium on dynamic	**Regulation of the firm** 'The impact of regulation on small business performance, BERR, April 2008. Survey data. There is a mutually interlocking relationship between regulation and performance which does not allow drawing the conclusion that one causes another. Government RIAs (regulatory impact assessments) Compliance cost studies available, though less on benefits of regulation and their influence on small business owners' activities and performances. Qualitative studies: • Awareness of regulation (Yapp and Fairman,	**Standards** DTI 'Empirical Economics of Standards': one of the most recent and comprehensive studies quantifying the value of standards to the economy. Investigates the role and impact of standardisation on economic performance: growth, productivity and innovation. The empirical economics of standards is only in its infancy. Macro-econometric study of the role of standards in Germany (1999) found standards were responsible for a significant proportion of growth in output of the German business sector between 1960 and 1996. Do standards enable or constrain	

	benchmarking. European TrendChart on Innovation: 35 country reports on innovation performance	2005) • attitudes to compliance (Petts et all 1999 and Vickers et al, 2005) • benefits of regulation (IpsosMori 2007) • dynamics of regulation on business decision-making & competitiveness (Arrowsmith et al 2003, Grimshaw and Carroll 2006) % of innovation active firms quoting factors of regulations and standards hampering innovation: CIS	innovating? Project conducted by Peter Swann considered relationship between standardisation and innovation using data from the CIS PENINORM database for intl. data on standards	
		Ability to make complementary investments Correlations between pairs of innovation activity • Intramural R&D • Extramural R&D • Machine. Eq. Software • Ext. knowledge • Training • Design • Marketing Source: UKIS2007 Mechanisms other than patents such as costs of imitation and investments in complementary assets as effective in appropriating returns from innovation: The Levin et al (1987) survey Investment in capital goods and equipment including computers and software is largest proportion	**Infrastructure/access to market** Communications infrastructure	

		of innovation expenditure, UKIS 2007. 'This can be equated to acquiring embedded technology including information and communications technology developments and shows the importance to national innovation performance of the diffusion of technical change.' Hampton Review 2005 NAO Report 2007		
			Marketing/media Business expend on innovation includes design and mkting UKIS. Also shows diff between mfg and svc and by size of firm. Intl comparison: EIS	

Discussion

'If you can't measure innovation and performance, you can't improve them.' IIIP, Hunter Centre for Entrepreneurship.

This paper accompanies the summary table of innovation indicators for the UK and in particular those which shed light on the wider conditions of the innovation process, including institutional and demand-side factors, the important extra-firm networks, linkages and collaborations and other issues which affect innovation conditions and indicators among different industry sectors.

Regulation

According to Innovation Nation:

> *The role of regulation in relation to innovation is complex – it can either act as a barrier by creating additional costs or as a promoter of innovation through creating incentives to produce improved products and services. Frequently, it must deal with competing objectives such as facilitating experimentation while simultaneously protecting individuals from harm and risks.*

There is therefore a trade-off between freedom and competition on one hand vs. regulation and predictability on the other. Too much regulation can destroy incentives from a competitive market. Since there is no universally agreed upon optimal amount of freedom or regulation, different societies have developed different sets of institutions which attempt to strike some sort of balance which will result from a society's institutions, its cultural values and the behaviour of its citizens, including its attitudes toward risky innovation.[28]

The Commission on Environmental Markets and Economic Performance has examined whether higher environmental standards have changed economic performance and created new markets and found that well-designed environmental regulation can drive technology forward. In the case of the water industry the Cave Review has also been formed to look into questions surrounding competition and innovation. But there has been no general examination of the practical ways in which regulation should be framed and implemented in order to have the greatest effect on innovation and in the ways in which technological change affects overall regulatory responsibilities and powers.

Whether regulation motivates changes in products or processes beyond minimum compliance, and the consequences for business performance depend also on the wider context within which particular businesses or sectors operate. Where businesses perceive products or process innovation

[28] Frans van Waarden, 'Institutions and Innovation: the legal environment of innovating firms.'

as essential to maintaining competitiveness, regulatory changes will probably motivate the search for new products and processes.

In April 2008, BERR published a study of the impact of regulation on small business performance, using qualitative data derived from studies of 124 small businesses in England. Their conclusion was that 'there is a mutually interlocking relationship between regulation and performance which in simple terms does not allow us to draw the conclusion that one construct (regulation) causes another (performance). The two constructs move together…though this does not include the dimension which relates to the costs of regulation.'

A recent estimate derived form the government's own regulatory impact assessments (RIAs) suggests that implementing new legislation has cost UK businesses more than £55bn since 1998. 'Reducing and simplifying regulations is not, however, and end in itself but a means to enhancing national economic performance and living standards for the UK population. The acid test of regulation, therefore, is whether it contributes to these broader policy objectives by producing the relevant outputs and outcomes at the firm level.' Compliance cost studies tend to reinforce the view of regulation as a cost or constraint (Chittendon, 2002). The benefits of regulation and its dynamic influence on small business owners' activities and performances are often neglected, though there are a small number of qualitative studies. Some of these probe questions about the extent to which regulations provide a firm an opportunity to gain a competitive advantage over other firms and to what extent the introduction of new regulations has encouraged the firm to take action to ensure its business remains competitive:

- Awareness of regulation (Yapp and Fairman, 2005)
- Attitudes to compliance (Petts et all 1999 and Vickers et al, 2005)
- Benefits of regulation (IpsosMori 2007)
- Insights into the dynamics of regulation on business decision-making and competitiveness (Arrowsmith et al 2003, Grimshaw and Carroll 2006)

In CIS3 67% of innovation active firms quoting factors hampering innovation between 1998 and 2000 cited the impact of regulation and standards. 20% of them cited these factors of high importance to hampering innovation.

Standards

One study of the impact of standards provided benchmarked estimates of the contribution of standardisation to long run productivity growth in the UK. It estimated the elasticity of labour productivity with respect to the number of standards to be bout 0.05. Because of the very high rate of growth of the catalogue, the researchers estimated the role of standards to have contributed around 13% of the growth in labour productivity in the UK between 1948 and 2002. Between those years the UK economy grew by 2.5% per year. The accumulation of labour and capital accounted for 1.5% and technological change from all sources 1%. Standards were associated with over one quarter of this latter figure. The study emphasizes that since standardisation acts in conjunction with other factors such as innovation, that the data did not permit the role of standards to be separated from other inputs.

Because they convey information, though, it is widely accepted that standards have a considerable role to play in stimulating knowledge-intensive activities such as innovation. Data from CIS3 validates the claim that innovators value the information content of public standards. However, standards can also hinder innovation if their timing is inappropriate. Too early, and a standard may shut out promising and ultimately superior technologies; or too late, and the costs of transition to the standard may be too high, preventing diffusion. Peter Swann found that the constraining role of standards varies in a non-linear way with the median age of the standards stock. 'It seems likely that both rather old and rather new standards constrain innovation – the first because it locks the innovator into legacy systems and the latter because it challenges the innovator.' As the number of standards relevant to a sector increases, producers are less likely to find standards as an impediment, but after a point, more standards increase the constraint on innovation.

One of the most recent and comprehensive studies quantifying the value of standards to the economy is the DTI's 'Empirical Economics of Standards, June 2005'. It investigated the role and impact of standardisation on economic performance, including growth, productivity and innovation. The programme consisted of three projects: benchmark estimates of the impact of public standards on technological change; standards and the international transmission of technology and whether standards enable or constrain innovation.

The empirical economics of standards is in its infancy. But there has been a macro-econometric study of the role of standards in Germany (1999) which found that standards were responsible for a significant proportion of the growth in output of the German business sector between 1960 and 1996. This was reckoned to be second in importance only to capital accumulation over the whole period – and more important than other sources of technological change, such as domestic innovation and the direct payment for imports of technology from abroad.

Market Structure

There does not appear to be a simple relationship between innovation and market concentration; both activities are the product of a number of economic relationships that vary across market environments, opportunities and chance. Simple tests of the explanatory power of market concentration find that it contributes little to an explanation of the variance in R&D intensity.[29]

Innovation may lead to increased concentration in situations where patent protection and trade secrets can 'insulate innovators.' Even without IP protection, innovators may be insulated from competition if the costs of duplicating unpatented new products are large (e.g. exceeding 50% of original innovation costs or network effects, learning or other structural characteristics of the market insulate first movers. Innovation might also reduce market concentration in leading to the growth of smaller firms or entry. When R&D is focused on the development of new products, it tends to be associated with lower market concentration; however when it is focused on the development of new production processes, it tends to be associated with higher levels of concentration.

Patents as Outputs and Inputs

Patent records offer the most comprehensive and detailed overview of technical knowledge over long time periods. They're often used as an intermediate output measure of innovation for a number of reasons including the fact that very long historical time series are available, showing only minor disturbances by occasional changes of patent laws or by major law court decisions. Patent databases are publicly available, have become increasingly computer readable and are classified in detail by technical field. It is even possible to assess the relative importance of patents by means of citation analyses.

Weaknesses of patents as innovation indicators include the fact that they miss many non-patented inventions and innovations. Some types of technology are just not patentable and there is an ongoing debate on other items, such as new business formulae on the internet. Firms sometimes use patents strategically – not to commercialise a produced, but in order to prevent a competitor from doing so. Furthermore, patents are not always easily classified by economically relevant industry or product line. Some patents reflect minor improvements of small economic value, while others prove to be extremely valuable and citation analyses may not be able to capture these differences. It has often been argued that the propensity to patent may differ across industries depending on the relative costs of innovation versus imitation. If imitation costs are relatively low, as in the pharmaceutical industry, firms will have a strong incentive to seek patent protection. And the opposite holds if imitation costs are relatively high. Empirical findings show that on average, firms do not consider patent protection to be the most important means of appropriating the benefits of innovation. In summary, when using patents as an indicator of innovation there are several types of potential systematic mistake:

[29] Philip Nelson, 'Relationship between market structure and innovation,' Economists Inc., 2002 and Symeonidis, 1996.

- underestimate innovation in low tech sectors
- overestimate activity among firms that collaborate on R&D
- underestimate the rate of small firms that innovate
- overestimate the innovation intensity of small-sized patent holders.
- focus on quantity rather than the quality of the rights
- lack standardisation across national systems
- reflect an outdated view of the innovation process as a linear process rather than a complex system with multiple feedback loops
- fail to take account of changes in the underlying IPR legal regimes, in the underlying science and technology base and the global and geographical dispersion of IPRs
- constrained by currently available methodologies used to construct IPR indicators.

Conversely, patents may also be viewed as measures of innovation input, as they are bought or licensed and used as a source of information by subsequent inventors. The intention of the new PATSTAT database will be to make it possible to construct more informative patent indicators which make them more effective as indicators of innovation. Though it will take some time before the new indicators are developed and universally accepted, some of the possibilities for this database are as follows:

- Weighting of patent applications by a measure of their value.
- Closeness to scientific R&D, measured as the number of citations of non-patent literature
- Knowledge spill over, geographical or across fields of science, based on patent citations
- Improvement of the IPC classification by including more and more detailed IPC codes
- Indicators based on the institutional sectors of the applicants
- Regional indicators, based on the addresses of the applicants/inventors
- Microdata – the patenting patterns of large and multinational companies
- Microdata – merging data on the patenting enterprises into innovation surveys or R&D surveys.

The patent system confers valuable property rights and can provide an important incentive to R&D effort, but does not appear to be the major source of private returns to innovative activity. Industries differ widely in the extent to which patents are effective: the evidence suggests that patents are regarded as a necessary incentive for innovation in only a few industries. There is evidence that patents are not perfectly enforced and also that many technologies are imitated very rapidly. One study found that about 60% of patented innovations are imitated within four years by 'innovating around' the patented product. [30]

An OECD study[31] on patents concluded:

> *Existing indicators are woefully inadequate for providing a sophisticated understanding about systemic linkages, the science-innovation interface, or the changing nature of the innovation process. Neither do they provide effective measurements of the increasing role of intellectual or knowledge-based assets in dynamic national and global economies.*

A conference on patent statistics will be held this September to discuss recent advances in their analysis, including the diffusion of technology, patenting activity by universities and links between technology, entrepreneurship and markets. The OECD patent project is working on developing an international statistical infrastructure for patents with a strong emphasis on the development of databases and methodologies. Issues include criteria for counting patents, triadic patent families, patents in selected technology fields. Reforming intellectual property law so that European inventors no longer have to spend three to 20 times as much for patent protection as Americans do.

Entrepreneurship

In recent times, there has often been a 'disconnect' between the research into entrepreneurship and that into innovation with questions often being pursued by different groups of researchers. The two have been identified as critical but separate contributors to economic growth and consequently policies have been designed and implemented by different parts of government. The convergence between entrepreneurship and their complementarities are not being optimised. Entrepreneurship involves the act of innovation but innovation systems often do not incorporate entrepreneurship as a major element. Fortunately, the need for indicators to measure the importance of entrepreneurship in innovation is more widely recognised.

Most current indicators of entrepreneurship come from GEM, the Global Entrepreneurship Monitor. Its surveys assess innovation in

[30] Mansfield, Schwartz and Wagner, 'Imitation costs and patents: an empirical study,' Economic Journal, 91(264), 1981.
[31] 'Creativity, Innovation and Economic Growth in the 21st Century: An affirmative case for Intellectual Property Rights,' a BIAC discussion paper, OECD, 2003.

entrepreneurial businesses in a variety of ways; one of which is an assessment of early-stage entrepreneurs and established business owner-managers concerning the novelty of their products or services relative to customers' current experience. A second way is the degree of competition faced by the business or whether the owner-manager perceives that many, few or no other businesses offer similar products or services. Early-stage entrepreneurs in high-income countries are more likely to perceive few or no competitors than their peers in middle- and low- income countries. Entrepreneurs with new products and those operating with few or no competitors are more prevalent among early-stage entrepreneurs than among established businesses. A workshop on EIS for 2008-2010 proposed using GEM as a source of data on early-stage entrepreneurial activity, in place of entry-exit rates, although there were concerns that this would measure aspirations, so that further exploration was necessary.

Culture and social norms

Recent years have seen an increased focus on the role of users and consumers in the innovation process, reflecting the significance of aggregated consumer demand in shaping innovation. These are areas where existing information is incomplete and where in particular it isn't possible to judge the comparative performance of the UK innovation system. However, a number of studies have documented the significant role that users have played in a number of specific innovations and fields. For example, four-fifths of novel innovations in scientific instrumentation were developed by users.

Business innovation surveys in the past have not routinely capture users as a distinct community. It's difficult to determine from current data how widespread examples of user-led innovation are. However, the example of open source software suggests that its role is likely to be of economic significance. The UKIS does not include a 'user' category. Probably the nearest it gets is a question that asks businesses about their innovation partners. In 2007 two-thirds said that 'clients or customers' were innovation partners. Not all of these will have been 'users.' The lack of general data also means that barriers to user-led innovation – and whether they represent a market failure – are difficult to identify in a general sense. The public infrastructure or knowledge sharing is likely to affect the degree of user-led innovation by affecting the ability of diffuse user communities to exchange information. Hence the intellectual property framework and provision of ICT infrastructure may speed up or impede user-led innovation. Users may respond quite differently from companies to financial incentives. Businesses themselves are investing in interactive ICT. However it is not clear whether conditions in the UK produce a significant departure form the optimal level of user-led innovation.

It isn't possible to determine how well user-led innovation process works across the entire UK economy. Eurobarometer surveys suggest an overall level of public readiness for innovation above the EU average although the proportion falls when asked more focused question on readiness to substitute new products and services for tried and tested alternatives. The DIUS/Research Councils' UK Public Attitudes to Science Survey 2008, showed that 25% of those polled agreed that "the more I know about science, the more worried I am." This was down from 35% in 2005. There are several other indicators of public readiness and acceptance of innovation including the following:

- Innobarometer: provides measure of innovation demand based on a survey of 30,000 Europeans.
- Public Attitudes to Science 2008 A Survey, DIUS. Some international comparisons available with use of Eurobarometer and research by the National Science Foundation. Comparisons available with surveys in 2000 and 2005. The results point a number of positive changes since 2005 and 2000. The UK population are more positive about science & engineering. Public opinion towards consultation, regulation and communication are mixed. Attitudes towards science were linked with sex, age and social grade.
- IIIP Innovation Confidence Index: willingness to buy new products or services, willingness to try products or services that involve new technology and belief that new products or services will improve one's life. As calculated, is significantly associated with national levels of entrepreneurship and economic growth, but not significantly associated with general consumer confidence.

So concerned is the government about public attitudes towards science and innovation that it set up Sciencewise Expert Resource Centre (ERC) funded by DIUS and launched in May 2008 as a tool for helping ministers and officials understand public views and concerns on complex and potentially controversial scientific issues.[32]

Diffusion via linkages, networks, collaboration

Linkages among actors have become increasingly recognised as a critical part of the innovation process. And whereas this was formerly an area not well captured in innovation surveys, it is now attracting far more attention. The European Innovation Scoreboard for 2008-2010 attempts to capture linkages with the following indicators:

- SMEs innovating in-house (% of all SMEs)
- Innovative SMEs co-operating with others (% of all SMEs)
- Firm renewal (SMEs entries and exits as a % of all SMEs)

[32] see 'Innovation: The Demand Side. New ways to create markets and jobs in Europe', Science Business December 2006.

- Scientific public-private co-publications per million population

Recommendations for other indicators to be considered in future include:

- Relative prominence of cited scientific literature capturing 'the relevance of IP and scientific advanced for innovation
- Percentage of international collaboration on S&E articles as a share of a country's total article output reflecting 'the international dimension in a country's knowledge base

Surveys have revealed something of how important firms consider extramural information sources. The proportion of UK businesses stating that universities or HEIs were of high importance as an information source was just 1% in 2007, whereas 27% of businesses rated clients or customers of high importance. Comparable data from other European countries for 2005 show a similar pattern: a relatively small proportion of businesses have very high levels of knowledge exchange with HEIs, research institutes and other similar providers of scientific expertise. Analysts of the UKIS point out that the proportion of businesses requiring access to leading edge scientific knowledge may be limited at any point in time; that the data measure the direct transmission of knowledge and underestimate the total contribution of research-based knowledge to businesses innovation from multiple sources and mean, such as indirect flows through publications, the operation of consultancies, codified standards and the movement of people. According to the UKIS, firms may at one time or another utilise all of the following sources:

- Own enterprise
- Suppliers
- Customers
- Competitors
- Consultants or private labs
- Universities or other higher education institutions
- Government or public research institutes
- Industry conferences or fairs
- Scientific or trade publications
- Trade associations
- Technical, industry or service standards

Enterprises say that they often collaborate more with their suppliers and customers than with specialist intermediaries and the research base, though taken together these are a major source of partners for innovation. Over a fifth of creative businesses have cooperation agreements, nearly twice as many as other industries. According to Professor Swann, it is well documented that only a relatively small proportion of companies collaborate directly with universities. The effects of innovation on range, market share and quality are greatest for those who collaborate with universities in Europe, but by contrast, the effects of innovation on capacity, costs and environmental impacts are greatest for those who collaborate with UK universities.

Industry Perspective

Discussions of innovation from an industry perspective have often focused on the 'lead market' concept, where industry and policy leaders focus on what has been successful in the past (such as Europe's now ubiquitous GSM system) in order to enable future successes in other industries. They talk of constructing instruments to spur market demand in strategic sectors, like zero-emission technologies to make public and private buildings carbon-neutral and energy-efficient. Are the relevant wider conditions discussed above the same for all industries or are some indicators more relevant than others for different sectors. In recent years, there has certainly been an attempt to broaden policy focus beyond bio and tech industries to encourage demand for creative, financial and retail industries. And even discussion in Europe of the reform of university management and tenure systems so that researchers think more about what industry and consumers need.

Business expenditure on innovation consists of the following components:

- Intramural R&D
- Extramural R&D
- Acquisition of machinery, equipment and software
- Acquisition of external knowledge
- Training
- Design
- Marketing

There are substantial differences in the composition of innovation expenditure across different business sectors. R&D accounts for about a tenth of innovation expenditure in the primary sector, construction, retail and other services, but accounts for over half of total expenditure in engineering-based manufacturing and two-fifths in knowledge-intensive sectors. Nearly half of all retail sector expenditure on innovation goes on marketing. So the wider conditions including culture and user-led demand may be more important innovation indicators in retail services than in other sectors. Indicators incorporating design and marketing might be appropriate here as the decision to introduce new or improved design is related to the ability of the firm to promote this innovation among its customers and market it as improvement in the goods or services it provides. Results of the UKIS reveal that only 3% of firms report investing in design without innovation-related marketing, while 18% invested in both

Most businesses do not systematically measure or manage innovation as defined in the Oslo Manual. Businesses often use broader performance measures; tight management of these acts as an incentive to innovate. Some of these measures are generic (such as revenue per employee) whereas others are very sector specific. In the retail sector, for example, sales or profit per square foot or floor space is used as a key performance indicator whereas these would make little sense in many other industries.
Business Monitor provides detailed breakdowns by product group and region of business R&D expenditure and funding. A number of analyses in recent years have suggested that at least part of the gap between the UK and other European countries may not be due to under-investment in R&D on the part of UK companies, but that the sector mix of the economy plays an important role in explaining these patterns. Business R&D in the UK is low as a share of total output because R&D intensive industries account for a smaller share of UK output than they do in some other leading economies. Data from company accounts show that UK companies in R&D intensive sectors invest at a comparable level to their competitors. This analysis demonstrates the need to supplement simple whole economy indicators with a more detailed understanding of disaggregated trends. According to the 2007 UKIS, UK businesses spend about £40bn a year on innovation; of this only a third is R&D. Investment in machinery, computer hardware and software accounts for a similar proportion and marketing-related expenditure represents a fifth of all innovation expenditure.

NESTA cites four types of innovation which are currently 'hidden' from measurement, but which are significant to the UK innovation system:

- Innovation that is identical or similar to activities that are measured by traditional indicators, but which is excluded from measurement, such as new technologies for oil exploration
- Innovation without a major scientific and technological basis, such as in organisational forms or business models
- Innovation created from the novel combination of existing technologies and processes, such as internet banking
- Locally-developed, small-scale innovations that take place 'under the radar', of traditional indicators and also of organisations and individuals working in a sector as in classrooms or construction teams.