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Innovation Indicators and the Knowledge Economy: Concepts, Results and Policy Challenges

Keith Smith

This paper discusses concepts of the knowledge economy, outlines some main 'robust' results from recent indicator development, and explores their policy implications. The results especially concern the prevalence of innovation across all sectors of the economy, the prevalence of 'system' phenomena, and the widespread creation of knowledge across sectors. The policy challenges relate to understanding the dynamics of the knowledge economy. Against this background the discussion will explore future policy and indicator challenges.

There have been major efforts in the field of innovation indicator development over the past decade, efforts driven both by policy concerns and by theorists and analysts. These initiatives led, for example, to the *Community Innovation Survey,* funded by the European Commission via Eurostat, and implemented in 1992-93, and again 1997-98. But there have been many other initiatives in indicator development: in labour market and education data, in inter-firm collaboration data, in data pertaining to organisation and human resource management, and in the integration of data sets.

What are the main policy and indicator challenges at the present time? Much policy discussion focuses on problems of change and transition, and on issues related to the 'knowledge economy'. The argument of this presentation will be first, that many concepts of the knowledge economy are unnecessarily narrow, and secondly that many widely-used indicators also have the effect of narrowing the focus of discussion of these issues by concentrating attention on a restricted range of industries or activities. This is particularly the case with R&D and patent data. The main challenge for the future is to use the full array of newly-developed indicators to understand the dynamics of innovation and knowledge creation in a much wider social and economic context. This means taking the full spectrum of economic activities into account - not just high-tech or ICT-based sectors, but the large mature sectors of the manufacturing economy, and in particular the service economy, both private and public. This will require a multi- indicator approach to analysis, and implies continued challenges for the consolidation of recent advances, and for new indicator development.

Introduction

Is it important to build direct indicators of innovation and knowledge creation? To what extent can we measure inputs and outputs of the knowledge creation process within firms? What are the policy uses of such indicators? This paper discusses recent attempts to measure innovation and knowledge creation, looking at the ways innovation measurement has been tackled, at the underlying conceptual issues, and at some of the main results and at remaining challenges.

There have been major efforts in the field of innovation indicator development over the past decade, efforts driven both by policy concerns and by theorists and analysts. From the policy side there has been an increasing understanding and awareness of the economic importance of innovation, and a tighter linkage between innovation policy and wider policy objectives. From the theoretical or analytical side, the study of the characteristics and impacts of innovation began to accelerate nearly thirty years ago and has now become a major research area for economic analysis and general social theory. These combined impulses have led researchers and institutions to seek to develop better quantitative indicators for innovation, and this means primarily indicators for knowledge.

The data generally available for innovation and technology analysis are essentially of four types. Firstly, there are data on R&D inputs, collected in the OECD economies according to the procedures and categories described in the "Frascati Manual"[2]. Secondly, there are patent data, the most important body of which consists of the records of the US Patent Office and the European Patent Office. Thirdly, there are bibliometric data on patterns of scientific publication and citation. Finally, there are various new types of data seeking to directly measure or indicate innovation processes across sectors: their inputs, outputs, objectives and so on. In addition to these major sources, there exists a wide range of what we might call '*ad hoc*' data sources, constructed usually by researchers to explore specific research issues.

The fact that these data sources have limitations is well known. R&D numbers only measure an input, which is not necessarily related to innovation outcomes. There are many examples of companies successful at innovating which perform relatively little R&D. Patent data are limited by variations in firms' and industries' propensity to patent. Moreover, such data tell us only about the invention phase of the innovation process. They tell us little about commercialisation and, hence, the economic value or economic impact of an invention. It may also be, as Keith Pavitt has argued, that R&D data underestimate the amount of innovative activity in small firms, while patent data underestimate innovation in large firms[3]. Bibliometric data tell us much about the changing shape of fundamental research, but little about the innovation process. Innovation data face a basic challenge in capturing all aspects of the novelty, learning and change which are involved in innovation.

The policy need for new innovation/knowledge indicators is based on recognition of the vital role of innovation in modern economies. This has sharply increased the importance of R&D and innovation policy. An especially important development is the increasing acceptance of the idea that we are entering a new type of 'knowledge economy'. However, this goal grew substantially in importance in the early 1990s as major institutions such as the OECD and the European Commission began the process of defining innovation indicators, and co-ordinating their implementation across countries. These initiatives led, for example, to the OECD's *Oslo Manual,* first published in 1992 and revised in 1997, it attempted to provide theoretical and methodological foundations and guidelines for new innovation indicators, and to the *Community Innovation Survey,* funded by the European Commission via Eurostat, and implemented in 1992- 93, and again 1997-98. The latter exercise has involved data collection from a very substantial number of firms: more than 40,000 in the first round, and around 100,000 in the second round.

Many of our problems with respect to the knowledge economy spring from inadequate indicators. Once we start looking at policy questions we immediately run into a situation in which the diagnosis of the causes of problems and the recommended solutions are sometimes based on very sparse evidence. For example, it is sometimes argued that labour mobility especially of researchers - is excessively low in Europe; but we don't have any general statistics to properly evaluate this. Similarly, from time to time it is suggested that innovation performance in Europe is less satisfactory than in the United States or Japan. Once again, we really do not have comparable data to determine whether this diagnosis is really true: for example, is it true that in general European innovation performance is relatively weak, or is this something which is true only of certain sectors or certain countries, or is it simply not true at all? Often, policy conclusions in Europe have been derived from case studies or partial statistics, because the type of empirical data that are needed to fully evaluate these issues have simply been missing.

1. Why are Measurement Issues Important in Innovation Studies?

Why is it important to have a statistical approach to innovation at all, rather than using case studies or other partial approaches, which incidentally have the merit of being cheap to perform compared to statistical work? The basic reason is that many theories about innovation or about its effects, for example theories of economic growth, really concern propositions about systems or populations. This means that the testing of these propositions should not be based on the generalisation of a few examples, such as those drawn from case studies. There is an enormous amount of extremely valuable case studies that have enriched our understanding of innovation, but these studies simply do not cover all relevant sectors or technologies. On the contrary, many of the innovation case studies of the past twenty years are focused on a relatively small group of R&D-intensive sectors of the economy. The result is that many innovation theories, particularly when extended to dynamics and growth theory, have only a tenuous link with economy-wide evidence. Since we are interested in the characteristics, structure, and dynamics of populations and natural systems as a whole, we need data that reflect the entirety of a population of firms.

We do, of course, already have some general indicators, particularly in the form of R&D statistics, patent data, and bibliometric data. But as noted above these indicators all have serious empirical limitations: in general, they allow us to look only at one piece of the innovation picture. The limitations of existing empirical data provides good reason for developing new indicators that can more fully encompass innovation processes.

Four approaches to the knowledge economy

Before we can think about relevant indicators, we need to consider the underlying concepts we are trying to measure. Leaving aside general definitional problems, there seem to be four basic views about the changed significance of knowledge:

Firstly, there are those who believe that knowledge is quantitatively and in some sense qualitatively more important than before as an input. Peter Drucker, for example, suggests that 'Knowledge is now becoming the one factor of production, sidelining both capital and labour.'[4] Along the same lines, the OECD has suggested that "the role of knowledge (as compared with natural resources, physical capital and low-skill labour) has taken on greater importance. Although the pace may differ, all OECD economies are moving towards a knowledge-based economy".[5]

Secondly, there is the idea that knowledge is in some way more important as a product than it has been hitherto - that we are seeing the rise of new forms of activity based on the trading of knowledge products.

Thirdly, there is the view that codified knowledge (as opposed to tacit, person-incorporated skills) is in some ways more significant as a component of economically-relevant knowledge bases. Thus Abramowitz and David argue that 'Perhaps the single most salient characteristic of recent economic growth has been the secularly rising reliance on codified knowledge as a basis for the organisation and conduct of economic activities'.[6]

Finally, there are those who argue that the knowledge economy rests on technological changes in ICT, since innovation in computing and communications changes both physical constraints and costs in the collection and dissemination of information. So for some, the rise of ICT technologies and the complex of ICT industries is coterminous with the move to a knowledge society. Lundvall and Foray argue a more sophisticated view: 'Even if we should not take the ICT revolution as synonymous with the advent of the knowledge-based economy, both phenomena are strongly interrelated the ICT system gives the knowledge-based economy a new and different technological base which radically changes the conditions for the production and distribution of knowledge as well as its coupling to the production system'.[7]

How valid are these claims? It is hard both to distinguish among and to assess these ideas, either in terms of the role of knowledge in general, or in trends. For example, when we speak of the 'knowledge economy' in a general way we should bear in mind that all economic activity rests on some form of knowledge, not only in our society but in all forms of human society. Looking to the recent past, the industrial economy of the nineteenth century was intensively knowledge-based, and many claims about the new 'knowledge economy' could plausibly have been made a hundred years ago. Indeed, nineteenth century commentators such as Andrew Ure and Charles Babbage claimed exactly that. Karl Marx argued that a distinguishing feature of mid-nineteenth century capitalism was 'the conscious application of science', and he explicitly treated separation of the conception and execution of tasks (that is, separation out of a knowledge function) as central to mechanisation.

What about the more specific claims outlined above? Let us look at them briefly, in turn. The point here is not to have a full discussion. It is simply that even a cursory examination can indicate the need for qualification of claims about the advent of a knowledge society.

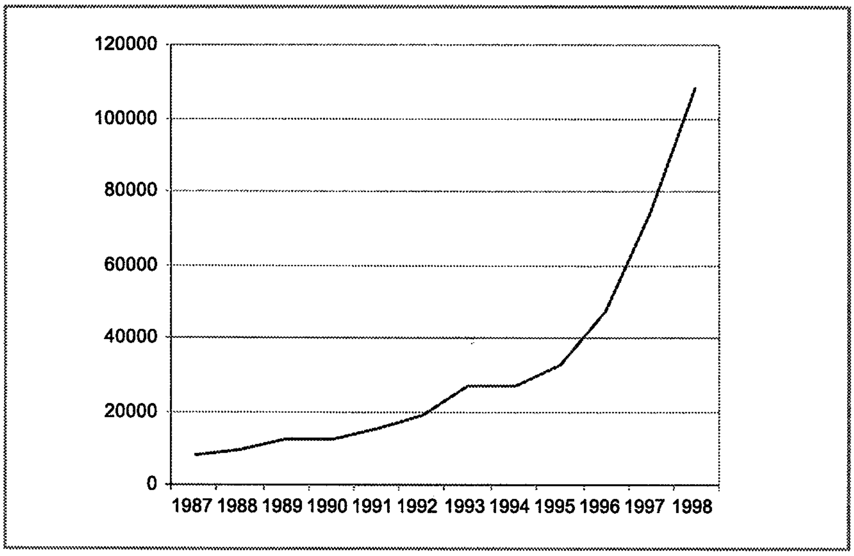
The argument that 'knowledge is sidelining capital' rests on the implicit idea that we can separate knowledge accumulation (and hence technological advance) from capital accumulation. While this idea is central to neo-classical production theory (it is the entire basis of the residual concept), it is highly questionable: knowledge cannot be incorporated into production except via investment, and the function of investment is often to implement new knowledge in production technology. There is no real ability to separate. At a more aggregate level, the claim that 'knowledge is sidelining capital' cannot be sustained by empirical data. The OECD has produced series comparing investment in physical capital and investment in 'knowledge' (meaning public spending on education, total R&D and software). For the OECD as a whole, physical investment is about two and a half times greater than 'knowledge' investment as a percentage of GDP. In terms of growth rates, 'knowledge' investment is growing faster than physical investment in the USA, the Nordic countries and France. But physical capital investment is growing faster than 'knowledge' investment in Italy, Japan, Australia, Belgium, Germany, Austria, the Netherlands and the UK.[8] The data do not therefore support any general claim that knowledge is increasing in importance in aggregate investment. Although it is common amongst polemicists to claim that knowledge is now in some sense more important than capital, there exists no substantive analysis which would substantiate this claim.

The notion that knowledge is more important as a product usually rests on claims about the growing significance of knowledge-intensive business services. Despite some rather tricky statistical issues in defining these services, and in determining whether some services are an independent source of growth or primarily an effect of vertical disintegration in manufacturing, the evidence is strong that these sectors are growing (certainly growing more rapidly than high technology sectors in manufacturing), and playing an important role in inter-industry diffusion of knowledge. There has been a strong growth in Europe and the U.S. in the share of business services in inter-industrial trade.[9] So there is good evidence that this is an area of real change, though it must be said that it remains relatively small as an activity. There has been of course a debate about whether this phenomenon represents a real change in knowledge use, or whether it is a statistical artefact driven largely by spin-offs from manufacturing. Be that as it may, the importance of this phenomenon lies not in such services as an autonomous source of growth, but as a connecting process within the innovation system. This should direct our attention to economy-wide aspects of the use of knowledge, rather than to knowledge products themselves as an independent activity.

In terms of the use of codified knowledge, there is no doubt that both the extension of formal education, and the uses of codified results of science are rising. In general, the only employment categories that are rising across OECD economies are those for people with higher education.

As regards codified science, perhaps the clearest indicator is the growth of citations to basic science in patents which has undergone a very sharp upward trend in recent years. The argument is that patents are becoming more heavily based on formal codified scientific and engineering knowledge, the evidence for which is citations to relevant literature on the opening page of the patent. Figure 1 shows the growth in the total number of citations in US patents to scientific and technical literature:

Figure 1 Number of citations on U.S. patents to scientific and technical articles: 1987-98



Source: National Science Board, Science and Engineering Indicators - 2000, Arlington, VA: National Science Foundation, 2000, p.6-54

However, both the education and patenting trends require careful interpretation it is not clear whether they are new, or whether they represent some new role for knowledge. For example, there is a long-standing debate about educational qualifications: do they represent a real knowledge input to production, or are they some kind of signalling mechanism in the labour market, referring to the capabilities of specific employees? If education provides some kind of direct input to production, then the links in terms of content ought to be traceable. This is clearly possible in some sectors (such as recruitment of molecular biology Ph.D.'s by pharmaceutical firms), but it is far less clear in others.

Then there is the role of ICT. Knowledge refers to understanding and competence. It is clearly true that ICT makes major changes to our ability to handle data and information. It is sometimes argued that there is a distinction between knowledge and information. The data moved or analysed by ICT methods are not themselves knowledge, and therefore ICT does not necessarily create or even extend knowledge. However this distinction between information and knowledge seems to me to be either a mistake or at least overdrawn, since neither information nor data can exist in the absence of background concepts and a knowledge referent. Nevertheless, ICTs are primarily an information management and distribution resource, and a major question that follows is, how does an information resource relate to the production and use of knowledge in society? Lundvall and Foray are almost certainly right in saying that ICT plays a new role in knowledge production and distribution, but this is a re-organisation of the technical and financial terms on which a resource (information) is available. It does not in itself expand the realm of accessible knowledge, let alone justify talking about a new mode of economic or social functioning. There is an empirical issue here as well, of course. If knowledge is a crucial input, and ICT is basic to its production, then seeing that the ICT revolution has been under way for at least twenty-five years there ought to be a robust relationship between ICT production, ICT investment and the growth of output and productivity. A series of studies have failed to demonstrate such a link.[10]

The claims sketched above rest on analytical and empirical support that varies from sophisticated (but questionable) to non-existent, and it seems that we are some way from really being able to assess the strength of these different perspectives, or whether they really add up to implying a new type of economy. Claims about the knowledge economy actually vary sharply in status. On the one hand, there are hand-waving exercises by special interests and various types of charlatan. On the other, there are serious attempts to disentangle elements of change in the current situation. The main problem faced by the serious literature is that most of the conceptual approaches to defining a knowledge society raise difficult empirical questions that are rarely followed through in the literature. The critical considerations sketched above therefore provide a problem for those who wish to speak of a new knowledge-based society. It is certainly true that knowledge accumulates over time, and that it changes the quality and quantity of output very significantly. But does this obvious point mean we are entering some new form of society that is qualitatively different in terms of the use of knowledge? The burden of proof here is on those who claim that the 'knowledge society' exists and is above all qualitatively new as a form of society. The conclusion suggested here is that none of those who have used the term have succeeded in conceptualising the phenomenon, let alone demonstrating that something new has happened. This does not mean that thinking in terms of knowledge is unimportant or irrelevant. It simply means that more care should be taken in formulating and using the term. Knowledge has been and continues to be a core foundation of the economic process. It remains important therefore for scholars and policymakers to have an adequate view of the relevance, structure and characteristics of knowledge across industries.

Knowledge-intensive industries?

Before moving to a discussion of knowledge in industry, it is necessary to make a diversion via the concept of 'high-technology'. In much policy analysis it is common to use the terms 'high-technology' or 'knowledge intensive industries' in a somewhat loose way, as though in fact they are both meaningful and interchangeable terms. But we ought to remember that the term 'high technology' is a rather recent invention, and that its meaning is far from clear.

The standard approach in this area rests on a classification developed by the OECD in the mid-1980s.[11] The OECD distinguished between industries in terms of R&D intensities, with those (such as ICT or pharmaceuticals) spending more than 4% of turnover being classified as high-technology, those spending between 1% and 4% of turnover (such as vehicles or chemicals) being classified as medium-tech, and those spending less than 1% (such as textiles or food) as 'low tech'. In fact, the OECD discussion of this classification was rather careful, and offered many qualifications. Chief among these is the point that direct R&D is but one indicator of knowledge content, and that technology intensity is not mapped solely by R&D. Unfortunately, the qualifications were forgotten in practice, and this classification has taken on a life of its own; it is widely used, both in policy circles and in the press, as a basis for talking about knowledge-intensive as opposed to traditional or non-knowledge-intensive industries.

This is a serious problem, since the OECD classification as it is used rests on only one indicator, namely intra-mural R&D. This is open to two important objections. First, it is by no means the only measure of knowledge-creating activities. Second, it ignores the fact that the knowledge that is relevant to an industry may be distributed across many sectors or agents: thus a low-R&D

industry may well be a major user of knowledge generated elsewhere. This issue will be discussed in a more empirical manner below.

Even so it is not clear that this classification helps us, even in a limited analysis of trends. One great problem is that in fact the high-tech sector thus defined is small, and therefore there are some difficulties in arguing that it is driving the growth process. In the OECD, for example, the USA has the largest share of high-tech in manufacturing, but this is only 15.8% of manufacturing output, which in turn is only 18.5% of GDP. So the high-tech sector is less than 3% of GDP. It is hard to see how either the direct or indirect impacts of such a small component of output could have a significant effect on overall economic growth. Most discussions of the role of high-tech are conducted in terms of share analyses, or even in effect - share-of-share analyses. This can easily confuse matters. In virtually all of the OECD economies the share of high-tech in total manufacturing has risen in the longer term, and this is widely used as an argument for the claim that such industries are central to growth. However this is complicated by the fact that that the share of manufacturing in total output has been in long-term decline. So between 1980 and 1995, the high-tech share of US manufacturing increased from 10.5% to 15.8%, while the share of manufacturing in GNP decreased from 21.6% to 18.5%. What this actually implies is that the share of high-tech manufacturing in total GNP rose over fifteen years by well under one percentage point.[12] It is not uncommon to see quite sweeping claims made for the high-tech sector which are not supported by readily available evidence. For example, OECD's *Knowledge Based Economy* claims that 'Output and employment are expanding fastest in high-technology industries, such as computers, electronics and aerospace'. But the OECD's own 'Scoreboard of Indicators' actually shows long-term *negative* growth rates of employment in high-tech manufacturing in eleven of fifteen OECD countries for which data are presented (including the USA, where high-tech employment declined at a faster rate than manufacturing employment generally).

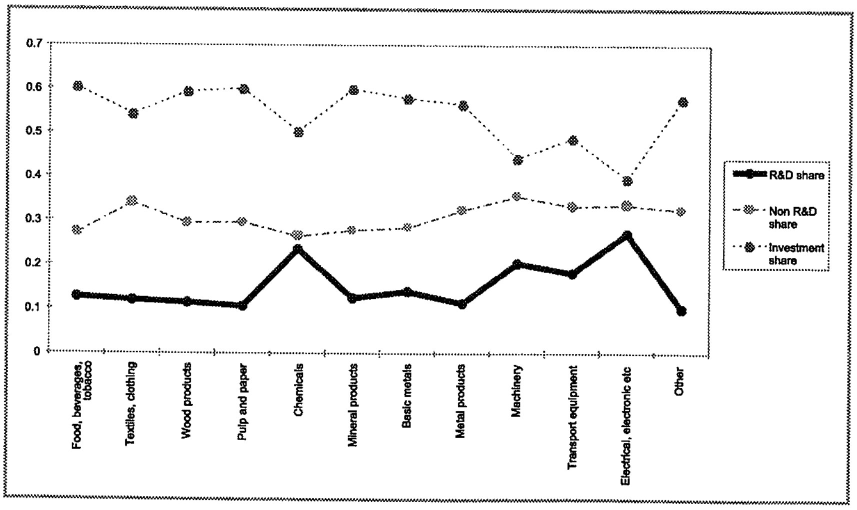
Such problems have not led to any questioning of the high-tech/low-tech distinction. On the contrary, the high-medium-low-tech approach has recently been extended, to divide the medium-tech category into medium-high and medium-low technology industries. Such classificatory manoeuvres cannot, however, alter the fundamental limitations of the category, and ought to cause us to question the identification of knowledge intensive and high-tech industries.

Firms and industry expenditures on knowledge creation: the empirical evidence

It is a mistake to identify knowledge creation with intra-mural R&D partly for conceptual and partly for practical reasons. Conceptually, R&D data tends to rest on a view of innovation that over-emphasises the discovery of new scientific or technical principles as the point of departure of an innovation process (an approach sometimes called the 'linear model' of innovation). It sees innovation as a set of development stages originating in research, and it is this prior significance of research that licences using R&D as a key knowledge indicator. From a practical point of view, the definitions of R&D in the OECD's Frascati Manual, which structure R&D data collection in OECD economies, exclude a wide range of activities that involve the creation or use of new knowledge in innovation. By contrast, modern innovation theory sees knowledge creation in a much more diffuse way. Firstly, innovation rests not on discovery but on learning. Learning need not necessarily imply discovery of new technical or scientific principles, and can equally be based on activities which recombine or adapt existing forms of knowledge. This in turn implies that activities such design and trial production (which is a form of engineering experimentation) can be knowledge- generating activities. A second key emphasis in modern innovation analysis is on the external environment of the firm. Firms interact with other institutions is a range of ways; these include purchase of intermediate or capital goods embodying knowledge. The installation and operation of such new equipment is also knowledge-creating. Then there is the purchase of licences to use protected knowledge. Finally, firms seek to explore their markets. Given that innovations are economic implementations of new ideas, then the exploration and understanding of markets, and the uses of market information to shape the creation of new products, are central to innovation. These points imply a more complex view of innovation in which ideas concerning the properties of markets are a framework for the recombination and creation of knowledge via a range of activities. In this framework R&D is important, but tends to be seen as a problem-solving activity in the context of innovation processes, rather than an initiating act of discovery. Many of the activities sketched above are in principle measurable. Collection of data on such phenomena has been attempted in probably the only systematic data source on non-R&D innovation expenditures, namely the Community Innovation Survey (hereafter CIS), which collects data not only on R&D but also on non-R&D innovation expenditures including training, market research related to new product development, design, expenditures on patents and licenses, and, most importantly, on capital investment (again related to new product development). In this section we draw on some results from CIS data from the Europe-wide survey of 1992, on the general firm and industry distributions of R&D and non-R&D expenditures on innovation. The data relate to the 1992 CIS, and the results are drawn from an EIMS report on innovation expenditures in European industry. We divide the data into three categories: capital investment related to new product development, R&D, and non-R&D expenditures (covering training, market research, design, trial production and tooling up, and IPR costs).

The first point, perhaps a rather obvious one, is simply that R&D is but one component of innovation expenditures, and by no means the largest:

Figure 1. - Composition of innovation expenditures by industry, all firms pooled, mean

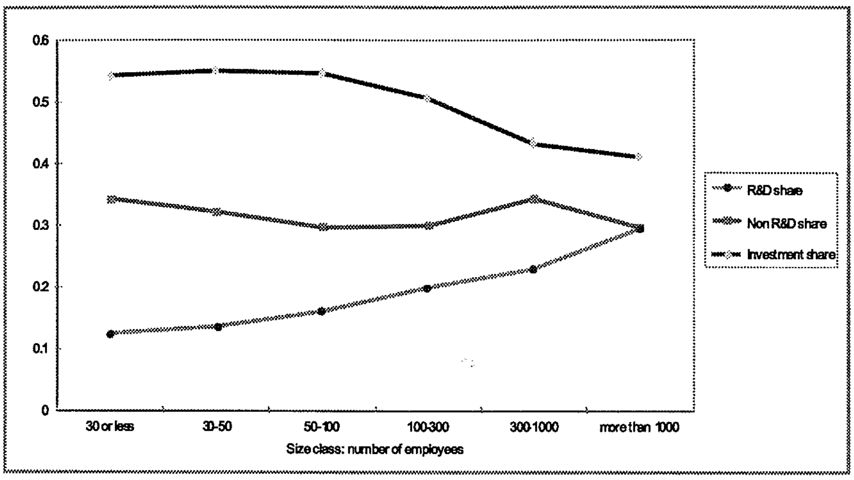


Source: Rinaldo Evangelista, Tore Sandven, Giorgio Sirilli and Keith Smith, Innovation Expenditures in European Industry, Report to the European Commission, DG-XIII-C, European Innovation Monitoring System. p. 46

There is, as we would expect, variation in the share of R&D expenditures in total innovation expenditure across industries, with electrical, electronics, and chemicals (here including pharmaceuticals) having high shares; this is exactly what we would expect from the R&D statistics. To this variation across industries there roughly seems to correspond a variation in the opposite direction for the share of investment expenditures: firms that have relatively low R&D shares have higher investment shares. This in turn implies that non-R&D expenditures (design, training, market research, etc.) vary somewhat less across industries. The mean R&D share by industry varies between about 0.1 and 0.25, the mean non-R&D share is generally close to 0.3, while the mean investment share varies between about 0.4 and 0.6.

Figure 2 shows the composition of innovation expenditures by size class for all countries pooled.

Figure 2 - Composition of innovation expenditures by size class, all firms pooled, mean



Source: Rinaldo Evangelista, Tore Sandven, Giorgio Sirilli and Keith Smith, Innovation Expenditures in European Industry, Report to the European Commission, DG-XIII-C, European Innovation Monitoring System. p. 47

What we have here is, once again, a rather consistent non-R&D expenditures share, but on the other hand a clear relationship between firm size and the share of R&D expenditures, with this share increasing consistently with firm size. To this there seems to correspond, though less clearly, a decrease in the share of investment expenditures with firm size. The implication here is that small firms rely more on the acquisition of capital goods in innovation expenditures, so that knowledge structures in SMEs are likely to be more heavily dependent on embodied knowledge within capital equipment.

Table 1 looks in more detail at these shares across both industries, for seven countries (Belgium, Denmark, Germany, Ireland, Italy, the Netherlands and Norway). We present the mean, standard deviation and coefficient of variation for each type of innovation expenditure and each industry. While there are inter-country differences in the basic data, the variances nevertheless tend to be low, suggesting that industry profiles do not vary significantly across the countries of Europe.

This data suggests a strong case for not focusing simply on R&D when we consider expenditure by firms and industries on innovation and knowledge creation, and suggest also a need to look into the significance of other sources of knowledge. It seems particularly important to look at capital investment, which represents a very significant component of innovation expenditure: in fact is the largest single component in every industry. In this context it is important to note that capital expenditure is a key mode of 'embodied' knowledge spill-over from the capital goods sector to using industries. Can we find a way of incorporating such embodied spillovers into our understanding of the knowledge intensity of the using industry by an empirical account of their knowledge contents?

Table 1 Innovation expenditures: shares by industry

	R&D			Non-R&D			Capital exp.		
	Mean	St.dev.	Coeff. var.	Mean	St.dev.	Coeff. var.	Mean	St.dev.	Coeff. var.
Food, beverages, etc,	0.11	0.03	0.30	0.27	0.03	0.12	0.62	0.03	0.05
Textiles, clothing	0.12	0.03	0.23	0.37	0.02	0.06	0.51	0.03	0.05
Wood products	0.16	0.18	0.12	0.27	0.06	0.23	0.57	0.19	0.34
Pulp and paper	0.12	0.03	0.26	0.31	0.04	0.13	0.58	0.06	0.10
Chemicals	0.24	0.05	0.20	0.25	0.06	0.23	0.52	0.03	0.05
Mineral products	0.12	0.05	0.45	0.30	0.05	0.17	0.58	0.07	0.13
Basic metals	0.17	0.04	0.26	0.25	0.06	0.26	0.59	0.06	0.10
Metal products	0.13	0.05	0.39	0.32	0.04	0.11	0.55	0.03	0.05
Machinery	0.20	0.03	0.16	0.37	0.05	0.13	0.42	0.06	0.13
Transport equipment	0.15	0.07	0.47	0.36	0.07	0.19	0.49	0.04	0.09
Electrical, electronic etc	0.28	0.05	0.18	0.31	0.03	0.11	0.41	0.03	0.08
Other	0.08	0.03	0.31	0.34	0.04	0.12	0.57	0.04	0.07

2. CIS: Some Main Results

What have we learned so far from attempts to measure and map innovation? In this section we look at some of the results which have emerged from a range of studies using CIS. Here, it is important to remember that the first round of CIS was very much a pilot project, and that there were many difficulties involved in the analytical use of the data. Nevertheless a wide range of studies have been carried out, mainly sponsored by actions within DG Enterprise. These studies have covered general features of innovation in Europe (input structures, output patterns, technology transfer, information flows, and employment, for example), as well as a wide range of sector studies, including chemicals, pharmaceuticals, machinery and engineering, telecommunications, computing, and so on.[13]

Innovation outputs

In this section we look essentially at results concerning two phenomena: firstly, the *pervasiveness* of innovation, and, secondly, the links between innovation and firm size. The first of these issues relates to a very important policy issue: is innovation something which is confined to high-tech, innovating sectors? Or does it occur across the whole economy? Does the usual policy focus on so-called 'high-tech' sectors really reflect the pattern of industrial innovation in our society?

The CIS data suggest considerable turbulence, in the sense that the product mixes of firms are subject to frequent technical change, with product mixes changing dramatically over quite short time periods. But it also shows pervasive innovation across sectors.

In general, the proportion of firms with innovation rises with firm size, across manufacturing as a whole. But how important is change in the product mix - 'creative destruction' among products - in those firms which have introduced new products? Table 2 indicates the relative proportions of sales deriving from 'products new to the firm', introduced to the market within the last three years, among innovative firms across five countries, broken down by industry. There are two primary points to note. The first is that the proportions are high: they imply complete change in product mixes at firm level over relatively short periods. The second point is that innovation in the sense used here is relatively evenly spread across all industry groups in all of these countries.

It is worth noting also that, across this group of countries, proportions of sales from innovative products do not differ radically across size classes of firms. Table 3 shows that if we exclude the smallest size class (10-19 employees) proportions of sales from new products vary little. This suggests a pervasiveness of innovation across not just across sectors, but across types of firms.

Using formal statistical methods, and covering a much wider group of countries, Calvert *et al* tested the link between firm size and new product sales, and showed that in only one sector (communications) was there a significant link between innovation output and firm size.[14]

Innovation expenditures

We noted above that the CIS collected data on a range of non-R&D innovation costs, namely product design, trial production, training and tooling-up, acquisition of products and licences, market analysis and other expenditures. But it also collected data on innovation-related investments, that is purchase of capital equipment which involved acquisition of new technology through investment in new machinery and equipment.

The study mentioned above by Evangelista *et al* asked whether, when analysing an industry, the extent or intensity of innovation expenditure was consistent across countries in Europe, or whether these levels varied across countries. The policy significance of this question lies in the fact that if the structure of innovation inputs is similar in the same industry across Europe, then there may a common European technological level, and it may be possible to identify appropriate arenas for European action in terms of RTD support.

The study showed that innovating firms commit significant resources to innovation, ranging from 7-8% of turnover in traditional industries to 12-15% in high-tech sectors. The composition of innovation costs varies, with between 10 to 25% made up of R&D, roughly 30% comprising non-R&D expenditures, and between 40 and 60% comprising investment expenditures. The levels of innovation expenditure (measured in terms of innovation expenditures as a proportion of turnover) are very similar across European industries in different Member States. This suggests that the intensity of innovation expenditure reflects features of the industry, rather than country-specific features.[15]

3. Future Challenges for Innovation Indicators

It is obvious that innovation policy must - if it is to be effective - be based on a serious and accurate understanding of the nature and effects of innovation itself. What has recent theoretical and applied analysis told us about these issues? And what are the implications of what has been learned, firstly for policy, and secondly for the development of indicators?

Although modern innovation research is very wide-ranging and heterogeneous, we would argue that there are three primary developments which have re-shaped both the research agenda and our understandings of innovation in its economic and social context. Consequently, these have both policy implications and impacts on our needs for quantitative data. The developments are as follows:

- The emergence of *interactive models of innovation,* in which linear notions of innovation have been superseded by models stressing interactions between heterogeneous elements of innovation processes. Innovation is thus seen in terms of complex interacting ensembles of activity, rather than sequential stages dependent on prior processes of scientific discovery. From the point of view of knowledge indicators, the key problem here is that we need indicators of knowledge creation that extend more widely than those of R&D, and which capture the range and extent of intangible investments in learning.
- *Systems theories of innovation and knowledge creation,* which are based on the crucial insight that firms never innovate alone, but always within the context of structured relations with other

firms, institutional infrastructures, networks, formal knowledge-creating institutions (such as universities or research institutes), legal and regulatory systems etc. Here, the need is for indicators which reflect the flows of knowledge between institutions, and which take us away from the focus purely on the innovating firm.

- *Incrementalist approaches to innovation*, based on awareness of the fact that innovation is widely spread: it does not consist simply of radical breakthroughs in high-tech manufacturing industries, but is often small scale and spread throughout manufacturing and the services sector (which - in quantitative terms - is far of greater importance to output and employment than manufacturing). We have very little in the way of indicators for the relevant activities here.

A basic issue in the development of innovation statistics, therefore, is that recent developments in theories of technological change and innovation, and in innovation policy, have outrun the ability of the available statistical material to provide either empirical evidence for theory, or adequate empirical grounding for policy. While the CIS is clearly a step forward in terms of the type and volume of innovation data which are available, it is nevertheless open to a wide range of criticism. Perhaps the most important of these relates to imprecision in the definitions of innovation. The basic problem is that the CIS definitions in terms of sales of changed products which are new to the firm concerned offer little guidance to the overall quality of innovation which is occurring. It is generally unclear just how much creative activity is involved in the types of innovation outputs which CIS measures, and this is an issue, since as Arundel has pointed out, 'When we talk about a firm expending a great deal of effort on innovation, we are not only speaking of financial investments, but of the use of human capital to think, learn and solve complex problems and to produce qualitatively different types of innovations.'[16]

We therefore face two types of challenge for the future, with respect to innovation measurement. The first is to improve our existing measures. The second is to develop new indicators for new areas of research and policy analysis, particularly with respect to processes of knowledge creation and distribution which lie outside the conventional indicators or R&D and patenting.