THE ECONOMICS OF KNOWLEDGE AND LEARNING

Bengt-Åke Lundvall
Department of Business Studies
Aalborg University
November 2003

Introduction

The focus in this book is on product innovation, learning and economic performance. A central theme is the understanding of learning and knowledge in connection with processes of technical and organisational change. In this chapter we present a conceptual framework to analyse knowledge and learning from an economic perspective. The starting point is the assumption that we are in a knowledge-based economy and we end by proposing that it is more adequate to characterize the current era as 'a learning economy'. Crucial questions to be analysed here have to do with distinctions private/public, local/global and tacit/codified knowledge. While appearing as somewhat 'academic' at first sight they have important implications both for innovation policy and for the management of innovation and knowledge at the level of the firm.

It has become commonplace among policy-makers to refer to the current period as characterised by a knowledge based economy and increasingly it is emphasised that the most promising strategy for economic growth is one aiming at strengthening the knowledge base of the economy[1]. This discourse raises a number of unresolved analytical issues. What constitutes the knowledge base? At what level can we locate and define a knowledge base? What are the specificities of local and sector specific knowledge bases? How stable is the knowledge base? In order to approach an answer to these questions three different themes are introduced: first, basic concepts related to knowledge and learning; second, the contribution of economic analysis to the understanding of the production, mediation and use of knowledge; and third, new economic trends and the formation of a "learning economy".

[1.] OECD has pursued several analytical acticitities along these lines (Foray and Lundvall 1996, OECD 1996). The Portuguese chairmanship for the EU Ministerial council for the first 6 months of the year 2000 were pursued under the theme of a Europe based on knowledge and innovation.

A terminology of knowledge

Is knowledge a public or a private good?

In 1987, Sidney Winter concluded a paper on knowledge and management strategy by pointing out that there is "a paucity of language" and "a serious dearth of appropriate terminology and conceptual schemes" for analysing the role of knowledge in the economy. Since then, the number of relevant publications has grown immensely, but little headway has been made in terms of a terminology acceptable to all. There is little agreement on questions such as: What is the meaning of knowledge and knowledge production? What separations and distinctions between different kinds of knowledge are most useful for understanding the interaction between learning, knowledge and economic development?

Knowledge and information appear in economic models in two different contexts. The most fundamental assumption of standard microeconomics is that the economic system is based on *rational choices made by individual agents*. Thus, *how much and what kind of information* agents have about the world in which they operate and how powerful their *ability to process the information* is are crucial issues.

The other major perspective is one in which knowledge is regarded as an *asset*. Here, knowledge may appear both as an input (competence) and output (innovation) in the production process. Under certain circumstances, it can be privately owned and/or bought and sold in the market as a commodity. The economics of knowledge is to a high degree about specifying the conditions for knowledge to appear as "a normal commodity", i.e. as something similar a producible and reproducible tangible product.

In what follows, attention is on knowledge in this latter sense. It raises the issue of how knowledge – in terms of competence and innovation – is produced, mediated and used. In analysing knowledge as an asset, its properties in terms of transferability across time, space and people are central. This issue is at the core of two different strands of economic debate. One is the public/private dimension of knowledge and the role of government in knowledge production, the second is about the formation of industrial districts and the local character of knowledge.

Is knowledge a private or a public good? In economic theory, the properties that give a good the attribute of "public" are the following: *i)* their benefits can be enjoyed by many users concurrently as well as sequentially without being diminished; *ii)* it is costly for the provider to exclude unauthorised users.

One reason for the interest in this issue is that it is crucial for defining the role of government in knowledge production. If knowledge is a public good that can be accessed by anyone, there is no incentive for rational private agents to invest in its production. If it is less costly to imitate than to produce new knowledge, the social rate of return would be higher than the private rate of return and, again, private agents would invest too little. Nelson's (1959) and Arrow's (1962b) classical contributions demonstrated that, in such situations, there is a basis for government policy either to subsidise or to take charge directly of the production of knowledge. Public funding of schools and universities, as well as of generic technologies, has been motivated by this kind of reasoning, which also brings to the fore the protection of knowledge, for instance by patent systems.

In a sense, this fundamental problem remains at the core of the economics of knowledge production. However, another strand of thought, that has roots far back in the history of economic theory, has become more strongly represented in the debate in the last decades. It is the question of how to share knowledge that is difficult to mediate. Marshall (1923) was concerned to explain the

real-world phenomenon of *industrial district*: why it was that certain specialised industries located in certain regions and why they remained competitive for long periods. His principal explanation was that knowledge was localised in the region and rooted both in the local labour force and in local institutions and organisations. This perspective, with its focus on localised knowledge, has, in the light of the Silicon Valley-phenomenon, resurfaced strongly among industrial and regional economists over the last decades. Correspondingly, the management literature has seen a growing interest in knowledge sharing within and between firms.

These two perspectives, while seemingly opposed in their contrasting emphasis on protection and sharing of knowledge, raise the same fundamental questions. Is knowledge public or private? Can it or can it not be transferred? Is the consent of the producer needed for the mediation to be successful or can knowledge be copied against the will of the producer? How difficult is it to transfer knowledge and what are the transfer mechanisms? Is it possible to change the form of knowledge so that it gets easier (more difficult) to mediate? How important is the broader socio-cultural context for the transferability of knowledge? One reason for the distinctions between different kinds of knowledge proposed below is that they help to sort out these questions.

Responding to these questions is also a way of specifying what constitutes the knowledge base of the economy. If knowledge were completely public it would be meaningful to speak of one common knowledge base for the whole economy and there would be a strong need for co-ordinating investments in knowledge production at the global level. If, conversely, knowledge were completely individual and private there would be no common knowledge base at all and investment in knowledge production could be left to the individuals themselves. As we shall see, reality is complex and most knowledge is neither completely public nor completely private. The knowledge base is fragmented and may best be illustrated as constituted by a number of semi-public "pools" to which access is shared regionally, professionally and through networking.

Four different kinds of knowledge

Knowledge is here divided into four categories which in fact have ancient roots (Lundvall and Johnson, 1994).[2]

- Know-what
- Know-why
- Know-how
- Know-who

Know-what refers to knowledge about "facts". How many people live in New York, what the ingredients in pancakes are, and when the battle of Waterloo took place are examples of this kind of

[2]. Knowledge has been at the centre of analytical interest from the very beginning of civilisation. Aristotle distinguished between: *Epistèmè*: knowledge that is universal and theoretical. *Technè*: knowledge that is instrumental, context specific and practise related. *Phronesis*: Knowledge that is normative, experience-based, context-specific and related to common sense: "practical wisdom". At least two of our categories have roots that go back to these three intellectual virtues. Know-why is similar to *epistèmè* and know-how to *technè*. But the correspondence is imperfect, since we will follow Polanyi and argue that scientific activities always involve a combination of know-how and know-why. Aristotle's third category, *phronesis*, which relates to the ethical dimension, will be reflected in what is to be said about the need for a social and ethical dimension in economic analysis and about the importance of trust in the context of learning.

knowledge. Here, knowledge is close to what is normally called information – it can be broken down into bits and communicated as data.

Know-why refers to knowledge about principles and laws of motion in nature, in the human mind and in society. This kind of knowledge has been extremely important for technological development in certain science-based areas, such as the chemical and electric/electronic industries. Access to this kind of knowledge will often make advances in technology more rapid and reduce the frequency of errors in procedures involving trial and error.

Know-how refers to skills – *i.e.* the ability to do something. It may be related to the skills of artisans and production workers, but, actually, it plays a key role in all important economic activities. The businessman judging the market prospects for a new product or the personnel manager selecting and training staff use their know-how. It would also be misleading to characterise know-how as practical rather than theoretical. One of the most interesting and profound analyses of the role and formation of know-how is actually about scientists' need for skill formation and personal knowledge (Polanyi, 1958/1978). Even finding the solution to complex mathematical problems is based on intuition and on skills related to pattern recognition which are rooted in experience-based learning rather than on the mechanical carrying out of a series of distinct logical operations (Ziman, 1979, pp. 101-102).

Know-how is a kind of knowledge developed and kept within the borders of the individual firm or the single research team. As the complexity of the knowledge base increases, however, co-operation between organisations tends to develop. One of the most important reasons for industrial networks is the need for firms to be able to share and combine elements of know-how. Similar networks may, for the same reasons, be formed between research teams and laboratories.

This is one reason why *know-who* becomes increasingly important. The general trend towards a more composite knowledge base, with new products typically combining many technologies, each of which is rooted in several different scientific disciplines, makes access to many different sources of knowledge more essential (Pavitt, 1998). Know-who involves information about who knows what and who knows what to do. But it also involves the social ability to co-operate and communicate with different kinds of people and experts.

How public or private are the four kinds of knowledge?

The public or private character of these kinds of knowledge differs in terms both of degree and form. Databases can bring together "know-what" in a more or less user-friendly form. Information technology extends enormously the information potentially at the disposal of individual agents, although the information still has to be found and what is relevant selected. The effectiveness of search machines developed in connection with the Internet is highly relevant in this context, as this helps to specify how accessible the data actually are. Even with the most recent advances in this area access to this kind of knowledge is still far from perfect (Shapiro and Varian, 1999). Even today, the most effective medium for obtaining pertinent facts may be through the "know-who" channel, *i.e.* contacting an outstanding expert in the field to obtain directions on where to look for a specific piece of information.

Scientific work aims at producing theoretical models of the *know-why* type, and some of this work is placed in the public domain. Academics have strong incentives to publish and make their results accessible. The Internet offers new possibilities for speedy electronic publishing. Open and public access is of course a misnomer, in that it often takes enormous investments in learning before the information has any meaning. Again know-who, directed towards academia, can help the amateur obtain a "translation" into something more comprehensible.

This is one strong motivation for companies' presence in academic environments and sometimes even engaging in basic research. Some big companies contribute to basic research and they tend to take over functions of "technical universities" (Eliasson, 2000). But at the same time, the close connections between academic science and the exploitation of new ideas by business in fields such as biotechnology tend to undermine the open exchange that has characterised academic knowledge production.

To gain access to scientific know why, it is necessary, under all circumstances, to pursue R&D-activities and to invest in science. This is true for individuals and regions as well as for firms. There is much less completely free "spill-overs" available than assumed in standard economics – absorptive capacity will reflect historical investment in R&D (Cohen and Levinthal, 1990).

In fields characterised by intense technological competition, technical solutions are often ahead of academic know-why. Technology can solve problems or perform functions without a clear understanding of why it works. Here, knowledge is more know-how than know-why.

Know how is the kind of knowledge with the most limited public access and for which mediation is the most complex. The basic problem is the difficulty of separating the competence to act from the person or organisation that acts. The outstanding expert – cook, violinist, manager – may write a book explaining how to do things, but what is done by the amateur on the basis of that explanation is, of course, less perfect than what the expert would produce. Attempts to use information technology to develop expert systems show that it is difficult and costly to transform expert skills into information that can be used by others. It has also been demonstrated that the transformation always involves changes in the content of the expert knowledge (Hatchuel and Weil, 1995). This is true of an individual's skills and competence, of professional skills and a team's competence. Eliasson (1996) has illustrated the limits of using management information systems as a substitute for management skills by pointing out the strategic failures of IBM and other big ICT-firms**.** Know-how is never a completely public good and normally firms get access to it only by hiring experts or merging with companies with the knowledge they want.

Know who refers to a combination of information and social relationships. Telephone books which list professions and databases which list producers of certain goods and services are in the public domain and can, in principle, be accessed by anyone. In the economic sphere, however, it is extremely important to obtain quite specialised competencies and to find the most reliable experts, hence the enormous importance of good personal relationships with key persons one can trust. These social and personal relationships are by definition not public. They cannot be transferred and, more specifically, they cannot be bought or sold on the market. As Arrow (1971) pointed out, "you cannot buy trust and, if you could, it would have no value whatsoever".

On the other hand, the social context may support, to a greater or lesser degree, the formation of know-who knowledge while the cultural context determines the form it takes. When characterising national business systems, Whitley emphasises factors having to do with trust and the capacity to build extra-family collective loyalties (Whitley, 1996, p. 51). This is also an important aspect of the concept of social capital (Woolcock, 1998; OECD, 2001). In situations where technology is characterised by rapid change or where the knowledge base is not well documented, it is necessary to meet face-to-face from time to time in order to solve problems.

Most knowledge is neither strictly public nor strictly private

It is clear from what precedes that very little knowledge is "perfectly public". Even information of the know-what type may be unavailable to those who are not connected to the right telecommunications or social networks. Moreover, the current state of information technology still

limits access for those who are in fact connected. Scientific and other types of complex knowledge may be perfectly accessible, in principle, but for effective access the user must have invested in building absorptive capacity. Know-how is never fully transferable since how a person does things reflects that individual's personality (even organisations have a "personality" in this sense).

On the other hand, little economically useful knowledge is completely private in the long run. Tricks of the trade are shared within the profession. Know-how can be taught and learnt in interaction between the master and the apprentice. New technological knowledge may be costly to imitate but, when it is much more efficient than the old, there are several ways to obtain it. Even when the possessor of private knowledge does not want to share it with others there are ways to obtain it, such as reverse engineering which involves taking products apart to find out how to produce them. If necessary, private agents will engage in intelligence activities aimed at getting competitors' secrets.

Different parts of economic theory handle this mixed situation differently. Underlying much of the neo-classical theory of production and economic growth is the simplifying assumption that there is a global bank of blueprints from which anybody can get a copy to be used for starting up production. This ignores the fact that most accessible knowledge can only be used by skilled agents and that skills differ and are not easily transformed into blueprints.

The resource base theory of the firm takes the opposite view and assumes that the competence of the firm determines the directions in which it expands its activities (Penrose, 1958). It is the specificity of the knowledge base that determines the specific pattern of economic growth. Actually, however, this model implies an even more dynamic perspective characterised by continuous creation of new competencies within the firm and it points toward the need to develop 'learning organisations'. Otherwise, imitation and innovations in competing firms would, sooner or later erode the firm's competencies.

In real life firms will have to engage simultaneously in copying well known routines from others, exploiting internal capbilities and engage in building new ones. This is what makes management a difficult art and why firms cannot be seen as maximising algorithms.

On tacitness and codification of knowledge

There is currently a lively debate among economists about the role of tacitness in knowledge. The reason for the interest is, of course, that tacitness relates to the transferability and to the public character of knowledge. It has been assumed that the more knowledge is tacit, the more difficult it is to share it between people, firms and regions. Specifically, markets might fail and other mediation mechanisms would have to be considered.

Tacit knowledge is knowledge that has not been documented and made explicit by the one who uses and controls it. The fact that a certain piece of knowledge is tacit does not rule out the possibility of making it explicit if incentives to do so are strong enough. To make this clear, it is useful to distinguish between tacit knowledge that can be made explicit (tacit for lack of incentives) and knowledge that cannot be made explicit (tacit by nature) (Cowan *et al.*, 1998).

Knowledge about the state of the world can to a certain extend be made explicit. Know-what can be entered into databases and know-why can be made explicit in theorems. Skills embodied in persons and competencies embodied in organisations can only be documented to a much more limited degree. There are "natural" limits to how far it is possible to make "know-how" explicit; only approximations are possible. This is why outstanding experts whose activities are based on their

unique know-how and firms whose activities are based on unique competencies and permanent innovation may earn extra rents for long periods.

An important issue in this context is how much effort should be made to "codify" knowledge. Knowledge written down in a code can be accessed only by those with access to that code. Two parties can share the knowledge or one party can sell the knowledge to another. Codified knowledge is potentially shared knowledge while non-codified knowledge remains individual, at least, until it can be learnt in direct interaction with the possessor. Sectors where the knowledge base is dominated by non-codified but potentially codifiable knowledge, may be sectors where systematic progress towards more efficient practices is difficult. Economists have used education as a typical example of a production process characterised by tacit techniques (Murname and Nelson, 1984).

The debate on codification has been complicated by the fact that two different kinds of codes have been alluded to. Some are explicit and available in the form of textbooks, manuals, formulas and organisational diagrams. Others have developed spontaneously as a means of communication within or between organisations (Arrow 1974). The latter are implicit and no individual in the organisation may be able to give a full description. The issue of the extent to which such implicit codes can be transformed into explicit ones is an important one. It is well-known that organisational diagrams and management information systems lose some of the complexity and richness that characterise social systems. If these codes could be made explicit, they could be made available to external parties, and mediation of knowledge would become less difficult. Another reason for making implicit codes explicit might be the fact that, in some instances, this would make it easier to formulate and realise strategies of change.[3]

What has just been considered as important attributes of knowledge (public/private; codified/tacit) suggests that there may be marked differences among various sectors with regard to their knowledge base. Some science-based sectors base their activities mainly on codified knowledge while others operate and compete mainly on the basis of unstructured and experience-based implicit knowledge. But there are no pure cases. Even in the most strongly science-based sectors tacit knowledge will be a key element in their competitive position and conversely it is difficult to find firms in the OECD area that can avoid completely the need to codify. Accounting and reporting to tax authorities requires a minimum in this respect and the wide diffusion of computers reflects the need to operate on the basis of codified knowledge (information).

An economic perspective on the production, mediation and use of knowledge

What is produced when firms produce knowledge?

Most authors using the concept of knowledge creation and knowledge production refer to technological knowledge and to technical innovation as the output of the process (Antonelli, 1999; Nonaka and Takeuchi, 1995). In the new growth theory, the output of the R&D sector is viewed either as a blueprint for a new production process that is more efficient than the previous one; it is assumed that it can be protected by private property instruments such as patents; or as a production of new semi-manifactured goods that cannot easily be copied by competitors (Verspagen, 1992, p. 29-30).

---

[3] For two different perspectives on the limits and the usefulness of codification see Cowan, David and Foray (2000) and Johnson, Lorenz and Lundvall (2001).

A striking characteristic of knowledge production resulting in innovation is the fact that knowledge, in terms of skills and competencies, is the most important input. In this sense, it recalls a "corn economy", in which corn and labour produce corn. But it differs from such an economy in one important respect. While the corn used to produce corn disappears in the process, *skills and competencies improve with use*. Important characteristics of knowledge reflect that its elements are not scarce in the traditional sense: the more skills and competencies are used, the more they develop. This points to knowledge production as a process of joint production, in which innovation is one kind of output and the learning and skill enhancement that takes place in the process is another.

Innovation as one major outcome of knowledge production

There are two reasons for regarding innovation as an interesting outcome of knowledge production. One is that innovation represents – by definition – something new and therefore adds to existing knowledge. The second is that innovation is – again by definition – knowledge that is in demand. (Innovation is defined as an invention that has been introduced in the market and it thus represents knowledge that has proven its relevance for the market economy.)

On the other hand, it is important to note that innovation, as Schumpeter emphasised, is part of a process of "creative destruction". An innovation may open up new markets and create the basis for new firms and jobs, but it will, at the same time, close down some old markets and some firms and jobs will disappear. This has a parallel in the impact on the stock of knowledge used in the market economy. Moral depreciation of intellectual capital is the other side of innovation. For instance, the know how necessary to produce mechanical office equipment and the competencies of firms engaged in their production became obsolete when semi-conductors and computers were introduced.

On the other hand, it is important to note that innovation, as Schumpeter emphasised, is part of a process of "creative destruction". An innovation may open up new markets and create the basis for new firms and jobs, but it will, at the same time, close down some old markets and some firms and jobs will disappear. This has a parallel in the impact on the stock of knowledge used in the market economy. Moral depreciation of intellectual capital is the other side of innovation. For instance, the know how necessary to produce mechanical office equipment and the competencies of firms engaged in their production became obsolete when semi-conductors and computers were introduced.

There are important sectoral differences in knowledge production. Such differences in the are reflected in the character, the mode and the outcome of the innovation process. The taxonomy developed by Keith Pavitt (1984) represents an important effort to capture these differences systematically. By analysing 2 000 important technical innovations in the United Kingdom, Pavitt defined four categories of firms and sectors. First, there are *supply-dominated* sectors (*e.g.* clothing, furniture), in which firms develop few important innovations on their own, but obtain some from other firms. Second, there are *scale-intensive* sectors (*e.g.* food, cement), which focus their innovation activities on developing more efficient process technology. Third, there are *specialised suppliers* (*e.g.* engineering, software, instruments), and these carry out frequent product innovations, often in collaboration with customers. Finally, there are *science-based producers* (*e.g.* chemical industry, biotechnology, electronics) which develop new products as well as processes in close collaboration with universities.

For a long time, knowledge production/innovation processes were considered largely as the province of the fourth category, and still there is a bias in this direction, often in combination with a

linear view which assumes that new scientific results are the first step in the process, technological invention the second step, and the introduction of innovations as new processes or products the third. There is now a very rich body of empirical and historical work which shows that this is the exception rather than the rule (Rothwell, 1977; von Hippel, 1988; Lundvall, 1988). Of all scientific advances, very few are immediately transformed into innovations and, *vice versa*, innovations very seldom reflect recent scientif ic breakthroughs. However, knowledge production/innovation processes are facilitated by science in various ways, although generally it is old rather than new scientific results that support the innovation process. Kline and Rosenberg (1986) have reviewed the complex interaction between science and technology throughout the innovation process.

The recent models of innovation emphasise that knowledge production/innovation is an interactive process in which firms interact with customers, suppliers and knowledge institutions. Empirical analysis shows that that firms seldom innovate alone. This is also the background for developing a systemic approach to knowledge production. Innovations systems are constituted by actors involved in innovation and their interrelationships. The actors are firms, technological institutes, universities, training systems and venture capital. Together they constitute the context for knowledge production and innovation. The specific constellations differ across sectors, regions and nations. They are typically specialised in terms of their knowledge base, and the specific mode of innovation will reflect institutional differences. This is the background for the growing literature on innovation systems (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997) and technological systems (Carlsson and Jacobsson, 1997). Innovation systems may be defined as regional or national, or as sector- or technology-specific. The common idea is that the specificities of knowledge production reflect unique combinations of technological specialisation and institutional structure. In national systems, the education and training system is among the most important for explaining national patterns and modes of innovation.

Competence as the other major outcome of knowledge production

The change from a linear to an interactive view of innovation and knowledge production has also been a way to connect innovation and the further development of competence. As now understood, the innovation process may be described as a process of *interactive learnin*g in which those involved increase their competence while engaging in the innovation process.

In economics, there have been various approaches to competence-building and learning. One important contribution is Arrow's analysis of "learning by doing" (1962a), in which he demonstrated that the efficiency of a production unit engaged in producing complex systems (aeroplane frames) grew with the number of units already produced and argued that this reflected experience-based learning. Later, Rosenberg (1982) introduced "learning by using" to explain why efficiency in using complex systems increased over time (the users were airline companies introducing new models). The concept of "learning by interacting" points to how interaction between producers and users in innovation enhances the competence of both (Lundvall, 1988). A more recent analysis of learning by doing focuses on how confronting new problems in the production process triggers searching and learning, which imply interaction between several parties as they seek solutions (von Hippel and Tyre, 1995).

In most of the contributions mentioned above, learning is regarded as the unintended outcome of processes with a different aim than learning and increasing competence. Learning is seen as a side-effect of processes of production, use, marketing, or innovation. An interesting new development, which refers to learning as an instrumental process, is the growing attention given to "learning organisations" (Senge, 1990). The basic idea is that the way an organisation is structured and the routines followed will have a major effect on the rate of learning that takes place. The appropriate

institutional structures may improve or speed up knowledge production in terms of competence building based on daily activities.

The move towards learning organisations is reflected in changes both in the firm's internal organisation and in inter-firm relationships. Within firms, the accelerating rate of change makes multi-level hierarchies and strict borders between functions inefficient. It makes decentralisation of responsibility to lower-level employees and formation of multi-functional teams a necessity. This is reflected in the increasing demand for workers willing to learn and, at the same time, skilful, flexible, co-operative and willing to shoulder responsibility. Inter-firm relationships with suppliers, customers and competitors become more selective and more intense. "Know-who" becomes increasingly important in an economy that combines a complex knowledge base and a highly developed, rapidly changing specialisation.

Apart from these organisational changes, there is a growing emphasis on making employees and teams of employees more aware of the fact that they are engaged in learning. It has been suggested that second-loop learning, *i.e.* a process in which the crucial element is that agents reflect on what has been learnt and on how to design the learning process, is more efficient than simply relying on the impact of experience (Argyris and Schön, 1978).

It is much more difficult to capture, empirically, competence building through learning than innovation. Competence is primarily revealed in practice and sometimes in no other way. This may become a problem as experience-based learning and competence become increasingly important for the competitiveness of workers, firms and regions. Tomlinson (1999) has made an interesting and original attempt to map sectoral differences in competence building through experience. Using UK labour market survey data, he shows that learning is more intensive and extensive in the top than in the bottom of organisations. His data also indicate that learning is more important in sectors characterised by frequent innovation. When it comes to the development of indicators, however, this is the most difficult but perhaps also the most important area.

These measurement problems reflect the general state of economic analysis in this field. While economists have made a very substantial contribution to the economics of innovation, their contribution to understanding competence building is much more modest. With scholars such as Christopher Freeman, Richard R. Nelson and Nathan Rosenberg as entrepreneurs and spiritual leaders, there has been a massive effort to understand the process of innovation in relation to economic theory (Dosi *et al.*, 1988) and in an historical and empirical perspective, including the development of statistical indicators. There is no parallel for knowledge production as learning and competence building. On this aspect of knowledge production, non-economists and education specialists have more to offer to economists in terms of systematic insights than *vice versa* (see, for instance, Kolb, 1984).

Production of knowledge as a separate activity or as a by-product of regular routine activities: a differentiation which is becoming blurred

It is useful to separate two different perspectives on the process of knowledge production which are not mutually exclusive but which can be found, in more or less pure form, in the literature on innovation systems and the information society. They are also reflected in attempts to measure the relative importance of knowledge in the economy and in theoretical models such as models of economic growth.

On the one hand, one might look for *a separate sector* in charge of producing new knowledge or handling and distributing information. Such a sector could involve universities, technical institutes and government S&T policies, as well as R&D functions in firms. Here, the production of

knowledge would take place as a deliberate activity, outside the realm of production. On the other hand, one might regard the creation and diffusion of knowledge as rooted in and emanating from routine activities in economic life, such as learning by doing, by using and by interacting. Here, the production of knowledge would take place as a by-product of production, through learning by doing or learning by using.

Another important distinction already touched upon is between deliberate and non deliberate forms of knowledge production, "off-line" and "on-line" learning activities. Above we referred to the growing focus on establishing learning organisations. Another related new trend is the emergence of a form of learning qualified as "experimental". This form of learning, which takes place "on line" (that is to say, during the process of producing the good or providing the service) consists in experimenting during the production process. By doing so, one creates new options and variety. This form of learning is based on a strategy whereby experimentation allows for collecting data, on the basis of which the best strategy for future activities is chosen.

With the emergence of experimental learning and learning organisations, the feedback and reciprocal links that tie "on-line" learning process and in-house R&D together become crucial. One issue here is determining the extent to which the knowledge produced "by doing" is valued. It might be a problem that routine activities are rarely considered by firm management as activities that produce knowledge, although different national systems differ markedly in this respect. The establishment of feedback loops requires effective recognition, identification and valorisation of the knowledge produced through the learning process.

Mediation of knowledge

While the production of knowledge is important for the overall dynamics of the global economy in the long run, the greatest economic impact comes from broadening the use of knowledge in the economy. This is reflected in public efforts to increase the diffusion of innovations as well as in training and education aimed at the formation of skills and competencies. How can different aspects of knowledge be mediated? The natural starting point for an economic analysis is to see under what conditions the market can mediate knowledge.

Some of the difficulties in mediating knowledge through the market have already been indicated. Tacit knowledge in the form of know-how or an implicit code or competence cannot be separated from the person or organisation containing it. This is what von Hippel (1994) calls "sticky data". In this case, mediation may take the form of the purchase by the customer of the services of the person or the firm rather than the competence itself.

Carriers of such knowledge may have a problem demonstrating the quality of their competence to potential buyers and buyers may have a problem locating the best offers in terms of quality. References from key customers which can be shown as evidence to potential customers is one strategy used by firms operating in this kind of market.

This form of mediation and the problems it involves tend to take on growing economic importance. The increasing specialisation in the production of knowledge makes mediation more crucial for the system as a whole. This is reflected in the fact that knowledge-intensive business services, a sector directly engaged in the production and sale of knowledge, are among the most rapidly growing sectors in OECD countries.

A second way to mediate this kind of knowledge is to engage in a process of interactive learning with the carrier of the knowledge. This may be a conscious choice, for example when an apprentice enters into a contract with a master, or it may be a side-effect of co-operation between people and

organisations to solve shared problems. A third way to obtain this kind of knowledge is to hire experts as employees or take over the organisation controlling the knowledge.

Even when knowledge is explicit and can be separated from its carrier there are problems with using the market as a mediator, which Kenneth Arrow, in particular, has worked to define. One is determining the value of the information for the user before the transaction takes place; a user wants to know something in advance about the knowledge, and the seller does not want to give information away for free. Another is the difficulty for the seller to restrict the use of the information once it has been sold and, *vice versa*, the difficulty for the buyer to restrict its further distribution by the seller.

Despite these difficulties, a large and growing amount of knowledge is the object of transactions in something that looks like a market (there is a buyer, a seller and a price). One reason why markets work is that formal and informal institutions – including legal protection in terms of patents, licenses and copyright – support transactions. Reputation mechanisms lower the risk for entering into contractual relationships. Another, even more fundamental, reason is that many markets for knowledge transactions are not pure but rather organised markets. Long-term relationships with elements of experience-based trust often play a major role in knowledge markets (Lundvall, 1985; Lundvall, 1988).

So far, the discussion has been limited to the mediation of what economists call disembodied knowledge. Substantial flows of knowledge are also built into products. Scientific instruments and computers embody a great deal of knowledge, and users with sufficient competence can perform very advanced operations with this kind of equipment. Mediation of knowledge via embodied technology is sometimes combined with a transfer of disembodied knowledge. For example, suppliers of complex process equipment may offer training to the personnel of the customer organisation.

Finally, knowledge can be mediated in several other informal ways. One way to overcome market limitations is for professionals belonging to separate and sometimes even competing organisations to exchange pieces of knowledge on a barter basis (Carter, 1989).

Codification of knowledge and the mediation of knowledge

The process of codification of knowledge plays an ambivalent role in the mediation process. On the one hand, the production and use of highly specialised codes or codes using technical or local jargon would actually create an obstacle to appropriation of the knowledge by lay people and potential users of the knowledge. On the other hand, a lack of codification may constitute an obstacle as users would not have access to sufficiently explicit knowledge. This ambivalence indicates the importance of designing and implementing metacodes or semicodes as mechanisms for developing compromises between the need to make knowledge more explicit and the need to avoid excessive technicalities and local jargons.

Towards the learning economy

Many indicators show that there has been a shift in economic development in the direction of a more important role for knowledge production and learning. This section looks at some of these changes and the issues they raise for the knowledge base of the education system.

Moses Abramowitz and Paul David (1996) have demonstrated that this century has been characterised by increasing knowledge intensity in the production system. The OECD's structural

analysis of industrial development supports their conclusion. It has been shown that the sectors that use knowledge inputs such as R&D and skilled labour most intensively grow most rapidly. At the same time, the skill profile is on an upward trend in almost all sectors. In most OECD countries, in terms of employment and value added, the most rapidly growing sector is knowledge-intensive business services (OECD, 1998, pp. 48-55).

These observations have led more and more analysts to characterise the new economy as "knowledge-based", and there is in fact little doubt about a relative shift in the demand for labour towards more skilled workers (OECD, 1994). However, this perspective may underestimate the destructive aspects of innovation and change. In an alternative interpretation of the change in the composition of the labour force, Anne P. Carter (1994) pointed out that the main function of most non-production workers is to introduce or cope with change. The rising proportion of non-production workers may thus be taken as the expression both of the growing cost of change and of an acceleration in the rate of change.

An acceleration in the rate of change implies that knowledge and skills are exposed more rapidly to moral depreciation. Therefore, the increase in the stock of knowledge may be less dramatic than it appears. An alternative hypothesis is that we are moving into a "learning economy", where the success of individuals, firms, regions and countries will reflect, more than anything else, their ability to learn. The speeding up of change reflects the rapid diffusion of information technology, the widening of the global marketplace, with the inclusion of new strong competitors, and deregulation of and less stability in markets (Drucker, 1993; Lundvall and Johnson, 1994; Lundvall and Archibugi, 2001).

In this context, learning is defined as a process, the core of which is the acquisition of competence and skills that allow the learning individual to be more successful in reaching individual goals or those of his/her organisation. It will also involve a change in context of meaning and purpose for the individual and affect his/her existing knowledge. This corresponds closely to what is commonly meant by learning and to what experts on learning, who are not economists, understand by the concept (Kolb, 1984). It is also the kind of learning most crucial to economic success. At the same time it differs from some definitions of learning in standard economic theory, where it is synonymous either with "information acquisition" or treated as a black box phenomenon assumed to be reflected in productivity growth.

Conclusions on the contribution of economic analysis to the understanding of knowledge base

It may be argued that, in a sense, all economic theory is about information and knowledge. Problems of co-ordination have been at the core of economic theory since Adam Smith. Individual agents make choices independently on the basis of information offered by the market. Important differences between economic models and theories reflect differences in the assumptions made about what agents know and about the degree to which they learn anything from what they do. This separates neo-classical economics from Austrian economics; the former takes fully informed agents as the reference, whereas the latter emphasises ignorance as the starting point for learning (von Hayek). It also separates those who assume hyper-rationality and rationality from those who assume limited rationality (Herbert A. Simon).

Modern economics is more than ever aware of the importance of knowledge and learning. New growth theory and new trade theory assume a strong link between the increase in the knowledge base and the rate of productivity growth. Austrian economists treat learning as a fundamental process in the analysis of market transactions. The last decades have witnessed an explosive growth

in institutional economics and the economics of innovation. In these new fields, knowledge and learning play a pivotal role in economic development. New theories of the firm focus on building capabilities and competencies. The management literature has made the concept of "learning organisations" central for theoretical developments and especially for practitioners.

However, in almost all of these contributions, the understanding of knowledge and learning remains narrow. In theories that form the core of standard economics, it is assumed that rational agents make choices on the basis of a given amount of information. The only kind of learning allowed for is agents' access to new bodies of information. The most recent developments within standard economics are contradictory and ambivalent in this respect. On the one hand, new growth theory and new trade theory focus on the importance of investments in education and research. On the other hand, some of the most fashionable developments in macroeconomics assume rational expectations and general equilibrium frameworks, thus operating with even more extreme assumptions, leaving no room for learning by agents.

Recent developments outside standard economics have been less constrained. Research on the economics of institutional and technical change has resulted in many new insights. Institutional economics, evolutionary economics, socio-economic research, industrial dynamics and the economics of innovation have typically been developed in close interaction with historical and empirical research programmes. This is why we now know much more than before about how innovation takes place in different parts of the economy.

When it comes to the other aspect of knowledge production, *i.e.* competence building and learning, research is only now beginning to raise fundamental questions about who learns what and how learning takes place in the context of economic development. In this area, economists have a lot to learn from other disciplines and not least from education specialists who have developed a much more systematic and empirically based understanding of learning (Kolb, 1984). This reflects the fact that when economists begin to focus on learning, they face issues for which their traditional toolbox is insufficient. Scholars in philosophy, psychology, education, anthropology and other disciplines have illuminated different aspects of these issues. The increasing division of labour in the production of knowledge – useful as it might have been for the rapid advance within special fields - has had as a major negative consequence the lack of a deep and systematic understanding of the complex process of knowledge creation and learning.

REFERENCES

Abramowitz, M. and David, P. (1996), "Technological change and the rise of intangible investments: The US economy's growth path in the Twentieth Century", in Foray, D. and Lundvall B.-Å. (eds.), *Employment and growth in the knowledge-based economy*, Paris, OECD.

Antonelli, C. (1999), *The microdynamics of technological change*, London, Routledge.

Arrow, K.J. (1962a), "The Economic Implications of Learning by Doing", *Review of Economic Studies*, Vol. XXIX, No. 80.

Arrow, K.J. (1962b) "Economic welfare and the allocation of resources for invention", in Nelson, R.R. (ed.) *The rate and direction of inventive activity: Economic and social factors*, Princeton, Princeton University Press.

Arrow, K.J. (1971), "Political and Economic Evaluation of Social Effects and Externalities", in Intrilligator, M. (ed.), *Frontiers of Quantitative Economics*, North Holland.

Arrow, K.J. (1974), *The limits of organisation*, New York, W.W. Norton and Co.

Arrow, K.J. (1994), "Methodological individualism and social knowledge", Richard T. Ely Lecture, in *AEA Papers and proceedings*, Vol. 84, No. 2, May 1994.

Carlsson, B. and Jacobsson, S. (1997), "Diversity creation and technological systems: A technology policy perspective", in Edquist, C. (ed.), *Systems of innovation: Technologies, institutions and organizations*, London, Pinter Publishers.

Carter, A.P. (1989), "Know-how trading as economic exchange", *Research Policy* , Vol.18, No. 3.

Carter, A.P. (1994), "Production workers, metainvestment and the pace of change", paper prepared for the meetings of the International J.A. Schumpeter Society, Munster, August 1994.

Carter, A.P., 1996, "Measuring the Performance of a Knowledge-based Economy", in Foray, D. and B.-Å. Lundvall (eds.), *Employment and Growth in the Knowledge-based Economy*, OECD Documents, Paris.

Cohen, W.M. and Levinthal, D.A. (1990), "Absorptive capacity: A new perspective on learning and innovation", *Administrative Science Quarterly* 35, pp. 128-152.

Dasgupta, P. and David, P. (1994), "Towards a new economics of science", *Research Policy*, Vol. 23.

David, P. (1991), "The computer and the dynamo; the modern productivity paradox in a not too distant mirror", in OECD, *Technology and productivity: the challenge for economic policy*, Paris, OECD:

David, P. and D. Foray (1995), "Accessing and expanding the science and technology knowledge-base", *STI-review*, no 16, Paris, OECD.

Drucker, P. (1993), *The Post-Capitalist Society*, Butter Worth Heinemann, Oxford.

Edquist, C. (ed.) (1997), *Systems of innovation: Technologies, institutions and organizations*, London, Pinter Publishers.

EIRMA, 1993, *Speeding up innovation*, conference papers for the EIRMA Helsinki conference, May

Eliasson, G. (1996), *Firm Objectives, Controls and Organization*, Kluwer Academic Publishers, Netherlands.

Foray, D. and B.-Å. Lundvall (1996), "The Knowledge-based Economy: From the Economics of Knowledge to the Learning Economy" in Foray, D. and B.-Å. Lundvall (eds.), *Employment and Growth in the Knowledge-based Economy*, OECD Documents, Paris.

Freeman, C. (1987), *Technology policy and economic performance: Lessons from Japan*, London, Pinter Publishers.

Freeman, C. (1991), "Networks of Innovators: a Synthesis of Research Issues", *Research Policy*, Vol. 20, No. 5.

Fukyama, F. (1995), *Trust: The social virtues and the creation of prosperity*, London, Hamish Hamilton.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Troiw, M. (1994), *The New Production of Knowledge*, Sage, London.

Hatchuel, A. and B. Weil (1995), *Experts in Organisations*, Walter de Gruyter, Berlin.

Kirzner, I.M. (1979), *Perception, opportunity and profit: Studies in the theory of entrepreneurship*, Chicago, Chicago University Press.

Kline, S. J. and Rosenberg, N. (1986), "An overview of innovation", in Landau, R. and Rosenberg, N. (eds.), *The positive sum game*, Washington D.C., National Academy Press.

Kolb, D.A. (1984), *Experiential learning*, Englewood Cliffs, Prentice Hall.

Lundvall, B.-Å. (1988), "Innovation as an Interactive Process – from User-Producer Interaction to the National System of Innovation" in Dosi, G. et al. (eds.), *Technical Change and Economic Theory*, London, Pinter Publishers.

Lundvall, B.-Å. (ed.) (1992), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter Publishers, London

Lundvall, B.-Å and Johnson, B. (1994), "The learning economy", *Journal of Industry Studies*, Vol. 1, No. 2, December 1994, pp. 23-42.

Marshall, A.P. (1923), Industry and trade, London, MacMillan.

Maskell, P. and Malmberg, A. (1999), "Localised learning and industrial competitiveness", *Cambridge Journal of Economics* 23 (2).

Murnane, R.J. and Nelson, R.R. (1984), "Production and innovation when techniques are tacit", *Journal of Economic Behaviour and Organization*, no 5, pp. 353-373.

Nelson, R.R. (1959) "The simple economics of basic economic research", *Journal of Political Economy*, vol. 67, pp. 323-348.

Nelson, R.R. (1993) *National innovation systems: a comparative analysis*, Oxford, Oxford University Press.

Nonaka, I. and H. Takeuchi (1995), *The Knowledge Creating Company*, Oxford University Press, Oxford.

OECD (1994), *The OECD Jobs Study*, Paris, OECD.

OECD (1996), *Transitions to Learning Economies and Societies*, Paris, OECD.

OECD (1998), *Technology, productivity and job creation*, Paris, OECD.

OECD (2000), Knowledge management in the learning society, Paris, OECD.

Pasinetti, L.L. (1981), *Structural Change and Economic Growth*, Cambridge, Cambridge University Press.

Pavitt, K. (1984), "Sectoral patterns of technical change: Towards a taxonomy", *Research Policy*, Vol. 13, pp. 343-73.

Pavitt, K. (1991), "What Makes Basic Research Economically Useful?", *Research Policy,* Vol. 20, No. 2.

Pavitt, K. (1998), "Technologies, products and organisation in the innovating firm: What Adam Smith tells us and Joseph Schumpeter doesn't", paper presented at the *DRUID 1998 Summer conference*, Bornhom, June 9-11.

Penrose, E. (1959/1995), *The theory of the growth of the firm*, Oxford, Oxford University Press.

Polanyi, M. (1958/1978), *Personal Knowledge*, London, Routledge & Kegan.

Polanyi, M. (1966), *The Tacit Dimension*, London, Routledge & Kegan.

Richardson, G.B. (1996), "Competition, innovation and increasing return", *DRUID Working Paper*, No. 10, Copenhagen Business School, Department of Industrial Economics and Strategy.

Rothwell, R. (1977), "The characteristics of successful innovators and technically progressive firms", *R&D Management*, No 3, Vol. 7, pp. 191-206.

Rosenberg, N. (1982), *Inside the black box: Technology and economics*, Cambridge, Cambridge University Press.

Shapiro, C. and Varian, H.R. (1999), *Information rules: A strategic guide to the network economy*, Boston, Harvard Business School Press.

Senge, P. (1990), *The fifth discipline: The art and practice of learning*, New York, Doubleday.

Teece, D., Pisano, G. and Shuen A. (1992), *Dynamic capabilities and strategic management*, University of Berkeley.

Tomlinson, M. (1999), "The learning economy and embodied knowledge flows in Great Britain", Journal of Evolutionary Economics, Vol.9, No.4, pp. 431-451.

Verspagen, B. (1992), *Uneven growth between interdependent economies*, Faculty of economics and business administration, Maastricht.

Whitley, R. (1996), "The social construction of economic actors: institutions and types of firm in Europe and other market economies", in Whitley, R. (ed.), *The changing European Firm*, London, Routledge.

Winter, S. (1987) "Knowledge and competence as strategic assets", in Teece, D. (ed.), *The competitive challenge: strategy for industrial innovation and renewal*, Cambridge, Mass., Ballinger Publishing Company.

von Hippel, E.(1988), *The Sources of Innovation*, Oxford University Press, New York and Oxford.

von Hippel, E. (1994), "Sticky information and the locus of problem solving: implications for innovation", *Management Science*, 40, pp. 429-439.

von Hippel E. & M. Tyre (1995), "How learning by doing is done: Problem identification and novel process equipment", *Research Policy*, vol. 24, no. 5.

Ziman, J. (1979), *Reliable Knowledge*, Cambridge, Cambridge University Press.