Modes of Innovation and Knowledge Taxonomies in the Learning economy

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Abstract

In evolutionary economics firms are seen as diverse. Diversity may be analysed in models where focus is on variance rather than on averages or on representative agents. Another way of capturing diversity is to establish taxonomies where firms are grouped according to one or more variables. When it comes to analyse 'the knowledge based firm' it is natural to look for taxonomies that refer to the knowledge base. Examples of such taxonomies are distinctions between high, medium and low-tech firms, the Pavitt taxonomy, distinctions between firms based on synthetic and analytic knowledge and, finally assuming that firms may belong to creative or non-creative industries.

In this paper we argue that such taxonomies may be problematic, in general, because they tend to freeze our understanding of the world. We go further and propose that they may be especially problematic in the current era (the globalising creative learning economy) since we are in a process where such distinctions are becoming increasingly blurred, especially in high-income regions. Responding to more intense and global competition *firms make attempts to compress and speed up processes of knowledge creation and learning* and to link creativity closer to production (using factories as laboratories). One way to do so is to integrate 'thinking' with 'doing' and, in this process, to combine synthetic with analytic knowledge.

Actually we will argue that for evolutionary economics focusing on *how firms combine different modes to create knowledge and engage in learning* may be more fruitful than attempts to characterise the knowledge base at a specific point of time. In a recent article in Research Policy (Jensen, Johnson, Lorenz and Lundvall 2007) we made a distinction between two modes of innovation. On the one hand we referred to innovation strategies that give main emphasis to promoting R&D and creating access to explicit codified knowledge (Science, Technology, and Innovation, *STI-mode*). On the other hand we defined innovation strategies mainly based on learning by doing, using and interacting (Doing, Using, and Interacting, *DUI-mode*).

Our results show that both in low technology and in high technology sectors firms that combine strong versions of the two modes are more innovative than those who practise only one of the modes. The results do not support attempts to make distinctions between high technology and low-technology sectors or between sectors operating on the basis of respectively synthetic and analytic knowledge.

Key words: Knowledge management, theory of the firm, interactive learning, learning economy**.**

Modes of Innovation and Knowledge Taxonomies in the Learning economy

Bob Anderson, Research Manager at Xerox, "..Both the pace and the acceleration of innovation are startling; nay terrifying....No-one can predict the ... range of skills which will need to be amassed to create and take advantage of the next revolution but one (and thinking about the next but one is what everyone is doing. The game is already over for the next)" (Anderson, 1997).

Introduction

This paper addresses isssues related to the first theme of the conference: 'the knowledge based firm'. The objective is to respond to the question asked by organisers: "How does the current state-of-the-art in evolutionary analysis, as pioneered by Schumpeter, Nelson & Winter, and others, help us to understand the role of firms in innovation processes, and innovation processes in firms? And what light does the new empirical evidence throw on this body of evolutionary thinking about firms and innovation?"

In evolutionary economics firms are seen as diverse. Diversity may be presented in theoretical models where focus is on variance rather than upon averages or assumptions about a representative agent. Another way of capturing diversity is to establish taxonomies where the firms are grouped according to one or more variables. In the case of the analysing the knowledge based firm it is natural to look for taxonomies that refer the knowledge base. Examples of such taxonomies are distinctions between high, medium and low-tech firms, the Pavitt taxonomy, distinctions between firms based on synthetic and analytic knowledge or assuming that there creative and non-creative industries.

In this paper we argue that such taxonomies may be problematic because they tend to freeze our understanding of the world and that in the current era (the globalising creative learning economy) we are in a process such distinctions are becoming increasingly blurred, especially in high-income regions.[1] Attempts to compress and speed up processes of knowledge creation and learning and to link creativity more directly to production require that firms integrate 'thinking' with 'doing' and synthetic with analytic knowledge.

Actually we will argue that for evolutionary economics focusing on *how firms create knowledge and engage in learning* may be more fruitful than attempts to characterise the knowledge base at a specific point of time. In a recent article in Research Policy (Jensen, Johnson, Lorenz and Lundvall 2007) we made a distinction between two modes of innovation. On the one hand we referred to innovation strategies that give main emphasis to promoting R&D and creating access to explicit codified knowledge (Science, Technology, and Innovation, *STI-mode*). On the other hand we defined innovation strategies mainly based on

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[1] In a conversation with Christopher Freeman about 20 years ago one of us (bal) expressed his admiration for the Pavitt taxonomy and its great usefulness. Chris responded that it was useful but added that it might be dangerous because it puts firms and sectors into rigid categories while reality is in a state of flux.

learning by doing, using and interacting (Doing, Using, and Interacting, *DUI-mode*).

In the first part of the paper we give a brief summary of the main results in this paper and on this basis we will argue that there is a need for innovative firms in all sectors to combine the two modes of learning. It is not possible to establsih clear distinction between firms that are based on synthetic and firms that are based upon analytic knowledge.

In the second part of the paper we argue that such distinctions become increasingly blurred in the current era of the globalising learning economy, especially in high-income countries. On the one hand scientific and codified knowledge becomes increasingly important as a source of competitiveness for firms in all sectors. At the same time the speed up of the rate of change requires that firms develop forms of organisation that make them more 'agile'. These changes imply that the distinctions between low technology- and high technology- firms tend to become blurred. And the same is true for the distinction between 'thinking' and 'doing' functions within firms.

Modes of innovation

In this part of the paper we analyse the tension and potential complementarity between two ideal type modes of learning and innovation. And we draw some implications for the understanding of the knowledge-based firm. One mode is based on the production and use of codified scientific and technical knowledge, the Science, Technology and Innovation (STI) mode, and one is an experienced-based mode of learning based on Doing, Using and Interacting (DUI-mode). At the level of the firm, this tension may be seen in the need to reconcile theories of the firm giving stronger emphasis to codified scientific knowledge and theories focusing on firms as learning organisations.

There are different discourses linking knowledge to the performance of the firm. One gives emphasis to the growing importance of science as source of innovation and to how the wide use of information technology makes codification of knowledge more attractive and less costly. Another discourse emphasises how firms, in a context of turbulence and rapid change in technologies and market demand, tend to establish themselves as 'learning organisation' in order to make processes of adaptation, innovation and learning. A third and more recent discourse emphasises creativity as the most important element in competition.

One difference between the three perspectives is that statistics on R&D, patents and scientists employed have become easily accessible while it is much more difficult to develop variables capturing creativity and the characteristics of learning organisations and to link those to innovative performance. In the case of creativity Florida has made some brave assumptions about what professional categories that do creative work. In what follows we argue that by focusing the analysis on the frameworks and structures that promote learning within and across organisations it is both possible to develop meaningful measures of DUI-mode learning and to demonstrate that firms can promote such learning through particular practices. Our empirical results show that the two modes of learning are practised with different intensities in different firms and that firms combining them are more innovative.

The STI-mode

The different types of knowledge may be related to differences in the two modes of learning and innovation we have identified. It will be easier to bring out these relationships if we start by recognising that technologies should be, "understood as involving both a body of practice, manifest in the artefacts and techniques that are produced and used, and a body of understanding, which supports, surrounds and rationalises the former" (Nelson, 2004, p. 457). Some of this understanding takes the form of empirical-based generalisations made explicit by practitioners about what works and what constitute reliable problem-solving methods. Although this kind of know-how may be specific to particular firms, much of it is more generalised knowledge common to wider professional or technical communities who work within the same technological fields.

However, as Nelson (1993, 2004) and others have observed, over the twentieth century most powerful technologies have come to be connected to and supported by different fields of science. As Brooks (1994, p. 478) notes, technology should be seen as incorporating generic understanding (know-why) which makes it seem like science. Yet it is an understanding pertaining to particular artifacts and techniques which distinguishes technology from science. The STI-mode of innovation most obviously refers to the way firms use and further develop this body of science-like understanding in the context of their innovative activities. Over the twentieth century, and still today, a major source for the development of this knowledge about artifacts and techniques has been the R&D laboratories of large industrial firms (Mowery and Oxley, 1995, Chandler, 1977).

The emphasis placed here on the way STI uses and further develops explicit and global know-why and know-what should not be taken to imply an insignificant role for locally embedded tacit knowledge. For instance, scientists operating at the frontier of their fields in the R&D departments of large firms need to combine their know-why insights with know-how when making experiments and interpreting results, and specific R&D-projects will often be triggered by practice, for example problems with new products, processes and user needs. We will still define it as predominately STI because almost immediately attempts will be made to restate the problem in an explicit and codified form. The R&D-department will start going through its earlier work, looking for pieces of codified knowledge, as well as looking for insights that can be drawn from outside sources. In order to communicate with scientists and scientific institutions outside it will be necessary to make knowledge explicit and translate the problem into a formal scientific code. In the empirical section of the paper we use R&D activities and collaboration with scientists attached to universities and research institute as indicators of the STI-mode.

All through the process, documenting results in a codified form remains important. It is not sufficient that the single scientist keeps results in his own memory as tacit knowledge. Often the project involves teamwork and modularization where single results are used as building blocks for other members in the team. At the end of the process – if it is successful - a transfer of the results within the organization or across organizational borders will call for documentation as well. In the case that an application is made for a patent the documentation needs to be made in a techno-scientific language that allows the patenting authority to judge the originality of the innovation.

This means that, on balance, the STI-mode of learning even if it starts from a local problem will make use of 'global' knowledge all the way through and, ideally, it will end up with 'potentially global knowledge' – i.e. knowledge that could be used widely if it were not protected by intellectual property rights. In terms of knowledge management it corresponds well to a strategy of knowledge sharing through wide access to codified knowledge inside the firm. The generalization of the knowledge in the form of a patent and the use of licenses will make it disembodied at least when compared to what comes out of the DUI-mode of innovation.

The DUI-mode

While science or scientific like understandings have increasingly come to illuminate and support technological practice, it is still the case that, "much of practice in most fields remains only partially understood, and much of engineering design practice involves solutions to problems that professional engineers have learned 'work' without any particularly sophisticated understanding of why" (Nelson, 2004, p. 458). This provides the first hint as to why the DUI-mode is crucial to successful innovation. This kind of knowledge, regardless of the extent to which it is ultimately codified, is acquired for the most part on the job as employees, including management experts and scientists, face on-going changes that confront them with new problems. Finding solutions to these problems enhances the skills and know-how of the employees and extends their repertoires. Some of the problems are specific while others are generic. Therefore learning may result in both specific and general competencies for the operator.

Both learning by doing and using normally also involve interaction between people and departments. In particular, an important result coming out of empirical surveys of the innovation process is that successful innovation depends on the development of links and communication between the design department and production and sale (Rothwell, 1977). These links are typically informal and they serve to transmit the tacit elements that contribute to making successful design that can be produced and that respond to user demands. As Lundvall (1992) and others have shown, these links extend beyond the boundaries of the firm to connect relatively small specialised machinery producers and business service providers with their mostly larger clients.

As the above discussion implies, the DUI-mode of learning most obviously refers to know-how and know-who which is tacit and often highly localized. While this kind of learning may occur as an unintended by-product of the firm's design, production and marketing activities, the point we want to make here is that the DUI-mode can be intentionally fostered by building structures and relationships which enhance and utilize learning by doing, using and interacting. In particular, organisational practices such as project teams, problem-solving groups, and job and task rotation, which promote learning and knowledge exchange, can contribute positively to innovative performance.

There is a vast business literature on 'high performance work systems' which examines the relation of such organisational practices to enterprise productivity and financial performance in general. (see, for example, Becker and Huselid, 1998; Osterman, 1994, 2000; Ramsay et al., 2000; Wood, 1999). One of the most interesting recent empirical results based on the statistical analysis of national or international survey data is that there is a positive relation between the organisational practices identified in this high performance literature and successful product innovation (Laursen and Foss, 2003; Lorenz et al., 2004; Lorenz and Valeyre, 2006; Lundvall and Nielsen 1999; Michie and Sheenan, 1999).

Illustrating empirically how DUI and STI-learning promote innovation

In what follows we will show that the probability of successful product innovation increases when the firm has organized itself in such a way that it promotes DUI-learning. We will also show that firms that establish a stronger science base will be more innovative than the rest. But the most significant and important result is that firms using mixed strategies that combine organizational forms promoting learning with R&D-efforts and with co-operation with researchers at knowledge institutions are much more innovative than the rest. *It is the firm that combines a strong version of the STI-mode with a strong version of the DUI-mode that excels in product innovation.*

For detailed information on the data and statistical methods used we refer to (Jensen, Johnson, Lorenz and Lundvall 2007. Here we will give a brief summary and focus on what we see as the most relevant results in relation to the topic of the workshop.

The empirical analysis is based on a survey addressed to all Danish firms in the private sector – not including agriculture. The survey collected information from management. We also have access to register data, allowing us to determine the workforce composition for the relevant firms. As the latent class analysis requires answers to all the questions considered in the analysis, the number of firms available for undertaking this analysis is 692.

Obtaining a meaningful quantitative measure of innovation and innovative behaviour on the basis of information collected in firms belonging to industries with very different conditions is not unproblematic. Our data indicate that for the most part we are confronted with incremental qualitative change rather than radical change when we ask the firms whether they, in the period of 1998 - 2000, have introduced new products or services on the market.

Developing indicators of STI and DUI-mode learning

Two of three measures we use to capture STI-mode learning are standard measures used to benchmark science and technology development in innovation policy studies: expenditures on R&D; and the employment of personnel with third-level degrees in science or technology. The third measure – cooperation with researchers attached to universities or research institutes – though of recognised importance is less commonly used in policy studies due to the lack of survey data.

For DUI-mode learning the choice of measures is based on a reading of two complementary literatures that deal with the characteristics of 'learning organisations': the 'high performance work system' literature referred to above (Clegg, et al., 1996; Dertouzos, et. al. 1989; Gittleman et al. 1998; Osterman, 1994, 2000; Ramsay et al., 2000; Truss, 2001; and Wood (1999); and the literature dealing with the relation between organisational design and innovation (Burns and Stalker, 1961; Mintzberg, 1979; Lam, 2005).

Table 1: Indicators of DUI and STI-mode Learning

Indicators	
DUI-mode learning	
Interdisciplinary workgroups	1 if the firm makes some use of interdisciplinary groups, 0 otherwise
Quality circles	1 if the firm makes some use of quality circles, 0 otherwise
Systems for collecting proposals	1 if the firm makes some use of systems for collective proposals, 0 otherwise
Autonomous groups	1 if the firm makes some use of autonomous groups, 0 otherwise
Integration of functions	1 if the firm makes some use of integration of functions, 0 otherwise
Softened demarcations	1 if demarcations between employee groupings have become more indistinct or invisible during 1998-2000, 0 if they are unchanged or have become more distinct
Cooperation with customers	1 if the firm has developed closer cooperation with customers during 1998-2000 to a high extent, 0 if to a small or medium extent or not at all
STI-mode Learning	
Expenditures on R&D as share of total revenue	1 if the firm's expenditures on R&D are positive, 0 otherwise
Cooperation with researchers	1 if the firm cooperates with researches attached to universities or scientific institutes rarely, occasionally, frequently or always, 0 if it never engages in these forms of cooperation
Indicator for workforce composition	Register data indicating whether a firm employs scientifically trained personal[2]. 1 if the firm employs scientifically trained personal, 0 otherwise

[2] Scientifically trained personal includes bachelors, master and Ph.D. students within the natural sciences as well as civil engineers.

The ‘high performance’ literature focuses on the diffusion of specific organisational practices and arrangements that enhance the firm’s capacity for responding to changes in markets and technology. These include practices designed to increase employee involvement in problem-solving and decision-making such as autonomous teams, problem-solving groups and systems for collecting employee suggestions. The first four of our six indicators of DUI-mode learning measure whether or not the firm makes use of the core high-performance work practices.

A similar contrast between rigid and adaptable organisations can be seen in Burns and Stalker’s (1961) distinction between ‘mechanistic’ and ‘organic’ organisations, or in Mintzberg’s (1979) distinction between the ‘machine bureaucracy’ and the ‘operating adhocracy’. In order to capture the difference between relatively hierarchical and rigid organisations on the one hand, and the more flexible and decentralised structure of learning organisations on the other, we included a measure of the extent to which functions are integrated and a measure of the extent to which demarcations are softened.[3]

In order to find out how the different DUI-measures are combined with the capacity to handle scientific and codified knowledge we have pursued a clustering across firms using latent class analysis. In the Research Policy we based the analysis on the 4-cluster solution.

The first cluster is a low learning cluster. It brings together firms that neither have highly developed forms of organizations that support DUI-learning nor engage in activities that indicate a strong capacity to absorb and use codified knowledge. The low learning cluster encompasses firms that do not spend on R&D nor cooperate with researchers. The latter may be explained by the fact, that these firms have a low probability of employing scientifically trained personal.

The second cluster, which we refer to as the STI cluster, encompasses about ten percent of the firms. Firms belonging to the STI cluster have activities that indicate a strong capacity to absorb and use codified knowledge. However, the firms in the STI cluster have rarely implemented organizational characteristics typical for the learning organization. The STI Cluster includes firms that have established the STI-mode without combining it with the DUI-mode.

The third cluster, which we refer to as the DUI cluster, brings together about one third of the firms in a group that is characterized by an over-average development of organizational characteristics typical for the learning organization but without activities that indicate a strong capacity to absorb and use codified knowledge. The firms in this cluster have a low probability of employing scientifically trained personal and their cooperation with researchers attached to universities or research institutes is below-average. This cluster includes firms that have introduced elements of the DUI-mode but are weak in terms of using the STI-mode

The fourth cluster includes firms using mixed strategied that combine the DUI and STI modes. It includes one fifth of the firms and these firms tend to combine the characteristics indicating

[3] In Appendix 1 the exact formulation of the questions and the distribution of the answers can be found.

a strong capacity for informal experience-based learning with activities that indicate a strong capacity to absorb and use codified knowledge.

Table 2: Logistic regression of learning clusters on product/service innovation

	Model 1 *(without controls)*		Model 2 *(with controls)*	
Variables	Odds ratio estimate	Coefficient estimate	Odds ratio estimate	Coefficient estimate
STI Cluster	3.529	1.2611**	2.355	0.8564**
DUI Cluster	2.487	0.9109**	2.218	0.7967**
DUI/STI Cluster	7.843	2.0596**	5.064	1.6222**
Business services			1.433	0.3599
Construction			0.491	-0.7120*
Manufacturing (high			1.805	0.5905*
Manufacturing (low			1.250	0.2229
Other services			0.747	-0.2923
100 and more			1.757	0.5635*
50-99 employees			0.862	-0.1481
Danish group			0.859	-0.1524
Single firm			0.521	-0.6526*
Customised product			1.378	0.3203
Pseudo R^2	0.1247	0.1247	0.1775	0.1775
N	*692*	*692*	*692*	*692*

** = significant at the .01 level; * = significant at the .05 level

In order to examine the effect of the learning modes on the firm innovative performance we use logistic regression analysis as reported in Table 2. The dependent variable for this exercise is whether or not the firm has introduced to the market a new product or service (P/S innovation) over the last three years. The independent variables in the Model 1 specification are binary variables indicating whether or not the firm belongs to a particular cluster. In the Model 2 specification we include control variables to account for the effects of industry, firm size, ownership structure, and whether the firm produces customised or standard products.

Using the static or low learning cluster as benchmark, the Model 1 results without controls show that the probability of introducing a new product or service to the market for firms belonging to the DUI-cluster this more than twice as high, while for the STI cluster the probability is more that three times. The difference is significant for both clusters. We find an almost 8 times as high a chance of P/S-innovation for the combined DUI/STI cluster firms and here the difference is also highly significant. [4]

When we add the control variables to account for the effects of size, sector, ownership and product type (Model 2), the difference observed in the probability of P/S innovation between the STI and DUI clusters disappears. For firms grouped in the combined DUI/STI cluster, the probability of innovating decreases substantially to approximately five times as high as for those grouped in the low learning cluster.

Overall, the results of the logistic analysis show that adopting DUI-mode enhancing practices and policies tends to increase firm innovative performance. Further, they support the view that firms adopting mixed strategies combining the two modes tend to perform better than those relying predominately on one mode or the other.

On the presence of the STI- and DUI-modes and High and Low-tech firms

In a recent interesting contribution Aasheim and Gertler (2005) have proposed that different sectors (and therefore different clusters) are more or less based upon *synthetic* and *analytic* knowledge. These two forms are quite strongly related to our distinction between DUI- and STI-learning. As can be seen below the authors tend to refer to *how* innovations take place when defining the specific category of knowledge and they also make a reference to an earlier version of the Research Policy paper summarised above:

> *'A synthetic knowledge base prevails in industrial settings where innovation takes place mainly through the application and or novel combination of existing knowledge. Often this occurs in response to the need to solve specific problems of arising in the interaction with clients and suppliers. Industry examples include specialized industrial machinery, plant engineering and ship building. R&D is in general less important than in other sectors in the economy.'*
>
> *'In contrast, an analytical knowledge base dominates economic activities where scientific knowledge is higly importan, and where knowledge creation is often based on formal models, codified science and rational processes. Prime examples*

[4] There may, of course, be reverse causality involved in these results in the sense that firms that succeed in innovating are better able and motivated to introduce DUI organisational traits and invest in R&D. This sort of problem, however, applies for any study that relies on cross-sectional data. What we show here is, simply that some sets of firm characteristics are good predictors of innovative performance.

are biotechnology and information technology. Both basic and applied research as well the systematic development of products and processes, are central activities in this form of knowledge production.
The importance of codification in analytic knowledge reflects several factors: Knowledge inputs are often based upon reviews of existing (codified) studies, knowledge processes are more formally organised.'

The idea is that certain clusters are based mainly on one or the other of these different kinds of knowledge and that there are interesting implications for why knowledge based economic activities appear to be localised and cluster in different types of clusters. We find the hypothesis interesting but in a sense in contradicts our idea that firms in all sectors need to integrate and combine the two modes of innovation in order to be successful.

Table 3: The frequency of the four clusters by firm size, sector, group ownership and production type (percent horizontal)

Variables:	Low Learning	STI Cluster	DUI Cluster	DUI/STI Cluster	*N*
Less than 50 employees	0.5605	0.0855	0.2566	0.0973	*339*
50 - 99 employees	0.3314	0.1775	0.3018	0.1893	*169*
100 and more employees	0.2457	0.1257	0.2686	0.3600	*175*
Manufacturing, high tech	0.2231	0.2645	0.2314	0.2810	*121*
Manufacturing, low tech	0.3522	0.1321	0.2893	0.2264	*159*
Construction	0.6139	0.0495	0.2574	0.0792	*101*
Trade	0.5780	0.0462	0.3064	0.0694	*173*
Business service	0.2727	0.0909	0.2576	0.3788	*66*
Other services	0.6512	0.0465	0.2791	0.0233	*43*
Danish group	0.4073	0.1371	0.2460	0.2097	*248*
Foreign group	0.2903	0.1694	0.2903	0.2500	*124*
Single firm	0.4890	0.0789	0.2776	0.1546	*317*
Standard product	0.3574	0.1687	0.2851	0.1888	*249*
Customized product	0.4518	0.0871	0.2635	0.1976	*425*
All firms	0.4249	0.1171	0.2673	0.1908	*692*

Our analysis in the Research Policy paper makes it possible to make a first *very crude test* of the proposal. Table 3 shows the frequency distribution of the different clusters by firm size, industry, group ownership and production. It is clear that the different clusters are distributed unevenly across industry, size and ownership. In terms of size, it is not surprising to find that relative to the population average the smallest firm size category is overrepresented in the low learning cluster. The other result that stands out is the marked overrepresentation of the 100 and over employee size category in the combined STI/DUI cluster.

But the most interesting distinction in table 3 is the one between firms belonging to high high technology and low technology sectors within manufacturing. The distinction is crude but all the sectors that Gertler and Aasheim refer to as being based upon synthetic knowledge are included in the low technology category while all the sectors they refer to as based upon analytic knowledge are included in the high technology category.

We find that 45% of the high technology sector firms do not have a strong version of the STI-mode – they are not based upon analytic knowledge according to the definition given above. We find that 35% of the low technology sectors do practise a strong version of the STI-mode – according to the definition they are based upon analytic knowledge. The data do not support the idea that we can put firms into separate categories on the basis of what kind of knowledge they make use of. But we recognise that there is a need for more sophisticated analysis to test the relevance of this taxonomic distinction.

The learning economy as context

In various contexts we have introduced an interpretation of what actually takes place in the economy under the term 'the learning economy' (Lundvall and Johnson 1994; Lundvall and Nielsen 1999). The intention is that the term should mark a distinction from the more generally used term 'the knowledge-based economy'. The learning economy concept signals that the most important change is not the more intensive use of knowledge in the economy but rather that knowledge becomes obsolete more rapidly than before; therefore it is imperative that firms engage in organizational learning and that workers constantly attain new competencies. In this second part of the paper we will argue that in the context of the globalising learning economy it becomes increasingly problematic to distinguish specific categories of High technology, Science-based or Creative firms.

A learning economy is one in which the ability to attain new competencies is crucial to the economic success of individuals and to the performance of firms, regions and countries. The background for the crucial importance of learning is that the combination of globalization, information technology and deregulation of formerly protected markets leads to more intense competition and to *more rapid transformation and change*. Both individuals and companies are increasingly confronted with problems that can be solved only through new competencies. The rapid rate of change is reinforced by the fact that the intensified competition leads to a selection of organizations and individuals that are capable of rapid learning, thus further accelerating the rate of change.

The transition to a learning economy confronts individuals and companies with new demands. We see the growing emphasis on new organization forms promoting functional flexibility and networking as responses to the challenge of the learning economy. In a rapidly changing environment it is not efficient to operate in a hierarchical organization with many vertical layers. It takes too long to respond if the information obtained at the lower levels should be transmitted to the top and back down to the bottom of the pyramid. In many instances relational contracting and networking enhance functional flexibility.

One important result from the first section is that the new organization forms which tend to support competence building through learning by doing and interacting tend to speed up product or service innovation. Another important result is that it is the combination of science-based and experience-based learning that promotes innovation. In the next section we will focus on how knowledge creation relates to innovation and to the establishment of learning organizations.

Innovation and knowledge creation

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 (Nonaka and Takeuchi 1995). In 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 or as a production of new semi-manufactured goods that cannot not easily be copied by competitors.

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.

Innovations as outcomes of knowledge production

There are two reasons for focusing on innovation when it comes to understand knowledge production. One is that innovation represents – by definition – something new and therefore adds to existing knowledge. The second is that innovation is a process where the innovating unit operates under uncertainty and therefore regularly is confronted with unforeseen problems.

The linear view 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 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). The recent models of innovation emphasize that knowledge production/innovation is an interactive process in which firms interact with customers, suppliers and knowledge institutions. Empirical analysis shows that firms seldom innovate alone (Lund Vinding 2002).

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

There are important sector differences in knowledge production. Such differences 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, so far as the manufacturing sectors are concerned. Pavitt defined four categories of firms and sectors.

- *supply-dominated sectors* (*e.g.* clothing, furniture)
- *scale-intensive sectors* (*e.g.* food, cement)
- *specialized suppliers* (*e.g.* engineering, software, instruments)
- *science-based producers* (*e.g.* pharmaceuticals, biotechnology, electronics)

We propose that there might be a need to critically review this taxonomy for two reasons. First the science-based firms increasingly need to connect their R&D-functions to the functions aiming at implementing, using and marketing the outcomes of creative processes. Second, The sectors defined as not being science-based tend to draw more and more on science when developing new products and services.

On the importance of organisational learning in science based firms

In May 1993 the European Industrial Research Management Association (EIRMA), organised its International Conference on the theme 'Accelerating Innovation'. In this context, it is relevant to quote from the introductory remarks of the EIRMA President, Dr. E. Spitz:

> " *In a time of intensive global competition, speeding up the innovation process is one of the most important ingredients which enable the company to bring to the market the right product for right prices at the right time........We know that it is not only the R&D process which is important we have to put emphasis on integration of technology in the complete business environment, production, marketing, regulations and many other activities essential to commercial success. These are the areas where the innovation process is being retarded (my italics). This subject is a very deep seated one which sometimes leads to important, fundamental rethinking and radical redesign of the whole business process. In this respect , especially during the difficult period in which we live today, where pressure is much higher , our organisations may in fact, need to be changed.* "(Eirma, 1993, p. 7).

The point made here is first that accelerating the process of innovation is critical for the competitiveness of science-based firms and second that this requires introducing new forms of organisation that speed up change and learning in all parts of the organisation.

One implication is that commercial success in firms that want to exploit R&D requires a speed up of the adaptation and learning processes in production and marketing. It corresponds to the idea that there in firms making use of the STI-mode is a need to apply a strong version of the DUI-mode.

On the importance for low tech firms to connect to science

Intensified and more global competition in traditional sectors such as clothing, food and furniture makes is more and more difficult for firms in high-income countries to operate on the basis of tacit knowledge and vocational skills. One way that firms have been able to respond to the increasing transformation pressure has been to mobilise scientific knowledge in their innovation processes.

Taking into account a number of factors that may affect the propensity to innovate we find a positive effect on the propensity to innovate (here measured as a positive response to the question if the firm has introduced a new product in a three year period) of having of employees with a graduate degree and of having establsihed closer relationships to knowledge organisations such as universities. What is interesting is that this effect is especially strong in small and medium-sized firms operating in low and medium technology sectors (see Lund Vinding 2004).

The role of graduates in small firm innovation has been analysed in a rigorous way in Nielsen (2007). The analysis is focused upon 200 small Danish firms originally without academic personnel, most of them operating in so-called low tech sectors. It studies the innovation performance in period t+1 distinguishing firms that hire a first graduate in period t from the rest. The analysis demonstrates that – taking into account a series of relevant control variables – the first-time hiring of a graduate with an engineering background has a significant positive impact on the propensity to introduce a new product (Nielsen 2007).

These studies demonstrate that the performance in terms of innovation is enhanced when firms coming from sectors dominated by the DUI-mode of learning move toward establishing elements STI-mode. This indicates that it is attractive for SMEs in traditional sectors to move in this direction.

From accidental to intentional learning

So far we have discussed characteristics of the learning economy that tend to point toward an integration of two modes of learning. In what follows we will discuss the same process in a different perspective. We will refer to how different functions within the firm tend to become closer linked both in time and space and how distinctions between them become increasingly blurred.

In economics, there have been various approaches to competence-building and learning. One important contribution is Arrow's analysis of 'learning by doing' (1962), 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 tends to see learning as a more instrumental process, is the growing attention given to 'learning organizations' (Senge 1990). The basic idea is that the way an organization 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 knowledge production in terms of competence building based on daily activities (Andreasen 1995).

The move towards learning organizations is reflected in changes both in the firm's internal organization and in inter-firm relationships. Within firms, the accelerating rate of change makes multi-level hierarchies and strict borders between functions inefficient. It makes decentralization of responsibility to lower-level employees and formation of multi-functional teams a necessity. This is reflected in the increasing demand for workers who are at the same time skilful, flexible, co-operative and willing to shoulder responsibility. It is also reflected in relationships with suppliers, customers and competitors becoming 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 specialization.

Apart from these organizational 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 and deutero learning, *i.e.* a process in which agents reflect on what has been learnt and on how to design the learning process, is much more efficient than simply relying on the impact of experience (Argyris and Schoen 1978).

A blurring of the distinction between production of knowledge as a separate (off-line) activity and as a by-product of regular routine activities (on-line)

It is useful to separate two different perspectives on the process of knowledge production which are not mutually exclusive in real life but which can be found, in more or less pure form, in the literature on innovation and 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 might, for instance, involve universities, technical institutes and government S&T policies, as well as R&D functions in firms. Here, the production of knowledge is assumed to 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, using and interacting. Here, the production of knowledge is assumed to take place as a by-product of in daily activities, through learning by doing or learning by using.

This distinction, between deliberate and non-deliberate forms of knowledge production, can also be referred to as respectively 'off-line' and 'on-line' learning activities. Above we referred to the growing focus on establishing learning organizations. Another related new trend is the emergence of a form of learning qualified as 'experimental' using 'the factory as a laboratory'. Both these forms relate to learning, taking place 'on line' (that is to say, during the process of producing the good or providing the service) but they reflect deliberate efforts to enhance competence building (OECD 2000).

The possibility of moving to this type of learning in more and more activities represents one important transition in the historical evolution of the learning economy. In effect, as long as an activity remains located either in a separate knowledge sector or gives rise only to non-reflective learning there remains a distinct cleavage between those who deliberately produce knowledge and those who are expected to use and exploit it. When more activities move to higher forms of learning where the individual can program experiments and reflect on results, the production of knowledge tends to become a more collectively distributed responsibility. The distance between the laboratory and the shop floor becomes shorter.

Creativity and innovation

One way to develop the idea of a stronger link between knowledge production and use is to refer to the debate on creativity. The work by Richard Florida links 'the creative class' to regional growth (Florida 2002). Recently it has been argued that 'creative industries' contribute with a big and growing share of national wealth and increasingly attempts are made to develop 'industrial policy' to promote such industries (Caves 2000).

Creativity normally refers to individuals' intellectual activities. WIKIPEDIA defines it as "a mental process involving the generation of new ideas concepts, or new associations between existing ideas or concepts". According to the same source it is distinct from 'innovation': "Innovation typically involves creativity, but is not identical to it: innovation involves acting on the creative ideas to make some specific and tangible difference in the domain in which the innovation occurs".

When we discuss creativity at the level of a system we need to consider not only the capability to create new ideas but also the capability to solve new problems. We will distinguish between agents that create new concepts and agents involved in the application and use of the new concepts. If creative agents are not balanced by agents that can *solve new problems* economic performance of organisations would suffer. This corresponds to a distinction between entrepreneurs as Schumpeterian 'innovators' and entrepreneurs as Kirznerian 'equilibrators'.

We therefore construct the following table:

Table 4: Critical processes linking creativity to economic performance

	Innovation	Equilibration
Creative thinking	1. New original ideas - formation of new paradigm.	3. Problem solving - normal science.
Creative doing	2. Creating new artefacts or business activities.	4. Discretionary learning by doing, using and interacting.

In principle we may be able to locate the dominant activities of individuals as belonging in mainly in one these four cells. Some scientists operate mainly in cell 1 but the majority operate in cell 3. Most artists may operate most of the time in cell 1 or cell 2. Some engineers operate mainly in cell 2 while the majority might actually operate in cell 4.

Normally when we think about promoting creativity we think about promoting and expanding activities in cell 1. But it is far from obvious that doing so would be beneficial for an organisation. Without linking thinking to doing the impact of new ideas will be limited. To have cumulative advance in science there is a need for some people to work on normalising the original ideas. If there is an overweight of innovators but a lack of people who are competent in solving the new problems that are created by the innovators the economy will suffer.

Separating creative thinking from creative doing?

In economic enterprise we can also find a more or less clear distinction between conceptualisation and realisation in different sectors. Major construction works will often take place on the basis of architectural designs and construction plans that should be followed as closely as possible by those realising the plans. It is interesting to note that the least innovative of all sectors seems to be construction (Lundvall 2001). This is a sector where the separation between the original idea and design and its realisation has been taken furthest apart.

In a context where accelerating innovation is a key to firms' competitiveness a clear separation between the creativity phase and the innovation phase may be especially problematic. Rather it tends to become two parallel and intertwined processes. The actual organisation of the innovation process will to some degree be sector specific and determined by the character of the technologies used. But as a general trend with the current emphasis on accelerating innovation we might be moving toward integrating creative thinking and creative doing into one process.

Creative site, creative class and creative industry

Increasingly experts and policy makers make clear distinctions between sites, social class and industry in terms of if they are creative or not. And often there is an implicit or explicit assumption that that making the creative sites, class and industries grow is an especially good thing for the economy. Actually a strategy where strengthen the creativity of non-creative sites, non-creative class and non-creative industries may be the one giving the highest rate of return on policy effort. Introducing creativity in rust-belt cities, among ordinary workers and in traditional industries is the absolutely necessary in order to cope with the impact of globalisation for the rich countries.

Summary

In the first part of this paper we have shown that firms that want to excel in innovation need to combine an innovation mode based upon experience based learning (DUI) with and innovation mode based upon science based learning (STI). The second part presents work in progress and some of the basic assumptions need to be tested in empirical work. The main message in the second part is simple.

First we argue that, in general, we need to be careful when applying taxonomies that distinguish between firms with reference to the knowledge base on which they operate. Such taxonomies have led both to simplistic analysis and to biased public policies where supporting high technology, science-based and creative firms has come to the top of the agenda and not always for rational reasons.

Second, we argue that such taxonomies tend to become especially problematic in the current era where firms in all sectors and operating in high income countries are forced to compress and accelerate innovation and knowledge creation. A result is that thinking and doing as well as creation and problem-solving have been brought closer to each other in time and space. Another possible conclusion is that a public policy that supports DUI-mode in STI-dominated firms and the STI-mode in DUI-dominated firms is especially called for in the current era.

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