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INTERACTIVE LEARNING AND TECHNOLOGICAL KNOWLEDGE: THE LOCALISED CHARACTER OF INNOVATION PROCESSES

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Interactive Learning and Technological Knowledge : the Localised Character of Innovation Processes

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1. INTRODUCTION

There is a growing insistence to consider economic systems are facing a period of structural change mainly characterised by a transition from a commodity exchange manufacturing system towards a weightless one. Advanced economies are facing the ultimate transition towards a service economy with a declining share of the gross national product generated in the manufacturing of physical goods. In such a transition the direct content of knowledge is enhanced and appears more and more important. This new context makes even more evident the limitations of an economic analysis traditionally based upon the biunivocal relationship between prices and quantities in all adjustment processes where changes in knowledge and in its distribution among agents could not take place.

Along such a transition, it becomes much more fuzzy to identify products characteristics as well as to understand the dominant regulation of economic activity because price mechanisms does not express anymore all the subtle aspects of 'exchange mechanisms'. Many scholars try to qualify those seemingly new conditions for the working of economic systems by referring to a so-called 'learning economy'. The development of the 'learning' or 'knowledge-based' economy is based on the fact that contemporary life is facing high qualitative changes, be the characteristics of production or markets. Both sides of economic systems appear very sensitive to rapid change, and expectations from firms and households as well seem to be much more volatile than they were in a recent past.

In this paper, we want to provide a critical analysis for this hypothesis of a transitory phase for economic systems. More precisely, we want to argue that the 'learning economy' has less to do with the usual definition of learning in economics than with co-ordination issues at different stages in the working of economic systems (see Amendola, Gaffard, 1988, 1998). If

we share the fact that the latter are facing continuous innovation processes, and that this situation seems to require a deeper attention on the conditions of learning characterising the economic functioning, we consider neither that this is a new phenomenon nor that learning is at central stake to understand the economic working of social societies. Considering that innovation has always been the source for economic growth, refining economic activity, be through the emergence of new capabilities or the strengthening of existing ones, has not to be thought of as a new requirement for economic systems. The emphasis on a learning economy mainly expresses changes in the conditions to innovate and this is essentially what will be under discussion within this contribution.

As noticed, the recent emphasis on a 'learning economy' results from the increasing volatility of commodities and from deep changes in the conditions to manufacture products, be the inputs involved, the related distribution networks, the customers' influence in design and technical specifications. As a consequence, considering a 'learning economy' essentially implies an ability to adapt to this new economic environment and a capability to set-up suitable tools and means in order to face this very evolving context.

Among the crucial aspects of this economic challenge, the conditions for firms' innovative behaviours to be economically viable require a specific attention. At first glance, it is possible to associate innovation to the production of new knowledge to be embodied in profitable activities. As a consequence, what appears very challenging is that economic systems are facing a context where the generation of knowledge has never been so much in proximity with its economic use. This questions the conditions of emergence, diffusion, and economic use of new knowledge. More precisely, this importance of knowledge in productive activities has to do with the debate on its localised character (Antonelli, 1995, 1999). In other words, we are

now facing a context where generation and diffusion of knowledge becomes specific, depending on the local conditions into which this knowledge is embedded. No mistake here: this 'localised' character of knowledge does not mean that it centrally refers to a geographical meaning. The localised character of knowledge has in fact to do with the architecture of firms' productive networking, that is the set of inputs and relations required to implement their activities. It can recover a geographical localised content but in main cases, the influential area of firms are world-wide and this localised character of knowledge is disconnected with geography and physical proximity. The localised character arises also and mainly from the idiosyncratic features of the bottom-up learning process associated with the techniques in use and the switching costs engendered by the irreversibility of sunk factors. Thirdly, the localised character is determined by the chains of weak and strong complementary effects among firms and among technologies which closely link the economic system and are appreciated in terms of economies of scope (if internalised) and externalities.

In this paper, we aim at exploring the consequences of the localised character of knowledge, as regards the central focus on co-ordination issues for economic systems.

2. THE NEED FOR A BETTER UNDERSTANDING OF TECHNOLOGICAL KNOWLEDGE

Actually, economics has already drawn attention on the importance of knowledge for firms' behaviours. Even if this attention is not new, and one can refer here to the fact that knowledge already was of central importance in Penrose (1959) to cope with the problem of the growth of the firm, recent considerations on knowledge are not completely satisfying because of their difficulty to cope with the very economic problem that firms are facing. Many of these attempts are considering knowledge for itself and focus on the conditions by

which knowledge becomes available to firms or diffuse within the economy. As a consequence, those economic attempts have incorporated learning in knowledge theories (Nonaka and Takeuchi, 1995) but there is, here, a misleading trend in the representation of the contemporary working of economic systems. One can think about the learning economy as the combination of two complementary blocks: one could be devoted to the production of new knowledge and encapsulate all the necessary infrastructure to provide the rest of the economy with new resources and knowledge including academics and scientific resources, R&D labs from large firms, 'high-tech' SMEs, and the like…; the rest of the economy could then be presented as benefiting from this set of competencies and capabilities that orient and organise the potential learning for the economy as a whole. Recent attempts in the economic literature toward the understanding of national systems of innovation can support such a view. But it fails to completely cover the conditions by which innovation occurs in firms by neglecting the other side of the knowledge problem. Knowledge also results from firms' daily activities in the sense it emerges from the set of routines, the usual working of production, and market interactions. However, on the one hand, no one can reject one or the other conception of knowledge-creating conditions as noticed by Foray and Lundvall (1996, p. 13) but, on the other hand, no one has actually provided a satisfactory framework to consider the interactive character of both dimensions. This is essentially due to the fact that the understanding of innovation cannot satisfy itself by a theory of knowledge. It requires more than that and especially a better understanding of how fundamental imbalances in resources induced by any process of change for firms' activities (mainly human and financial imbalances) are managed over time.

On the opposite, our analysis elaborates on an approach where agents are able at each point of time to generate new knowledge and to try to make use in their specific market and

production contexts. A bottom-up approach to the generation of technological knowledge, as distinct from scientific knowledge, finds a clear reference in the analysis put forward by Hayek (1937, 1945) and Richardson (1960) on the role of economic knowledge in the market place. Successful technological innovations are the result of a discovery, as opposed to invention. The actual discovery of new suitable technologies emerges in the market place, in out-of-equilibrium conditions, where agents do more than adjusting prices to quantities and viceversa. A variety of new technologies at each point in time and space is tested in the market place and sorted out. Further recombination and integration of localised knowledge together with the creation of appropriate coalitions of users and producers may eventually generate successful technologies.

In this context, the understanding of the specific mechanisms by means of which new knowledge is generated, recombined, experimented and eventually applied, becomes a key issue. An issue which cannot be separated from the specific competitive and productive context into which firms' conducts and strategies are embedded. Complementary effect among agents in the identification of appropriate technological solutions, as guiding post for the formation of effective coalitions, is key to understanding such dynamics. A dynamics where competition often follows sequentially co-operation is selecting and assessing the basic technological requirements and interfaces.

This is the reason why we intend to focus on a specific definition of knowledge, that we will recall as 'technological knowledge'. Technological knowledge is not used in this paper accordingly to its usual definition. Technological knowledge is more than technological resources in that it incorporates a specific ability to organise, control and combine technological resources with the aim of making the firm profitable as well as ensuring its

ability to change its activities over time. Technological knowledge has more to do with the localised character we previously referred to. Technological knowledge incorporates the interactive character that a company has to manage with its productive environment. This of course refers to other firms being involved as suppliers of resources for production but it also refers to customers and their influence in the working of production processes and well as non-productive organisations such as business associations, banking institutions as well as science and technology institutions. Taking all this set of components into consideration appears as a necessary condition to the understanding of the localised character of technological knowledge, i.e. to the understanding of the conditions firms are facing to ensure the evolution of their activities from an economic viewpoint.

3. SOME EMPIRICAL EVIDENCE ABOUT THE LOCALIZED CHARACTER OF TECHNOLOGICAL KNOWLEDGE : CONTRASTING SECTORAL EXAMPLES

Because of the interactive character of technological knowledge, there is an obvious need to consider in more details the huge variety in the mechanisms and designs suited to its production. There are contrasting sectoral patterns that show the relevance of the localised character of technological knowledge for economic reality. This is due to the complexity of productive requirements as well as the variety of its implications in terms of interfirms' relationships. In that respect, we can shortly learn from empirical contexts and elaborate on sectoral differences in the way by which firms are facing technological knowledge.

There are important difficulties in order to express sectors' diversity as regards the emergence and diffusion of technological knowledge. The method we have chosen consists in mapping sectors' characteristics, according to a list of variables we consider central to qualify firms' formal and informal relationships. The latter include factors purely internal to firms (be

technology and organisation factors), information related to markets' characteristics, and environmental variables related to the institutional infrastructure to which firms are confronted.

In the telecommunication industry, firms are evolving in a multitechnological context and facing an explosion of potential uses. On the supply side, this industry is composed of different layered activities: the equipment supply (terminal equipment, network equipment); the network provision (lines, switches, backbones); the service provision (short and long distance telecommunications, mobile telecommunications, data transmissions, the Internet); the entertainment provision (edition, multimedia, broadcasting, virtual reality, software and middleware); the commercial and distribution level. On the demand side, some new requirements emerge: the necessity to have simultaneous access to different types of information (texts, audio and video documents); the communication within or between different groups of users; the user-friendliness, mobility, reliability and safety of communication protocols. Technological knowledge has here to do with the capability to reduce mismatches between the supply and demand sides, during that transformation process faced by that specific industry. Communication and knowledge channels have for central aim to co-ordinate knowledge flows so as to reconcile technological opportunities with market potentialities in a context which is facing rapid changes, be the supply or demand sides of the industry.

A contrasting example to telecommunications lies in the Aircraft industry where no significant mismatch between the supply and demand sides of the sector is noticeable. On the contrary, an obvious stability characterise producers-users' relationships. However, the industry is facing high turbulence due to the very high innovative character of technological

knowledge within the industry. If the products made by the leaders of this industry are stable in the long run, the conditions by which those products are made as well as the technologies they incorporate are rapidly changing. Here, the organisational design among the set of firms involved in aircraft industry (be large firms, large-SMEs relationships, or KIBS) is central to be considered as far as the understanding of technological knowledge is concerned. Aircraft industry outputs are system-products that require a complex network of inter-firms relationships from the conception stage to the manufacturing. This complex system of productive relationships makes especially relevant the analysis of how knowledge emerges and can be shared among those partners, and how it is organised to conduct the strategy of continuous technological innovation that characterises the evolution of this industry as well as explains its international competitive success.

The development of the so-called 'life sciences' industry offers an example of a more informal structuring for an industry and, consequently, for its capability to produce and diffuse technological knowledge. Structural uncertainty in terms of productive potentialities are stronger in that case because of academics and consumers pressures. Life sciences-industry actually refers to a set of industrial activities where knowledge is continuously renewed, re-organized and where the generation of knowledge from academics flows very rapidly and through complex communication channels into industrial applications. As such, this industry appears very interesting to show how diverse are the ways by which institutional and productive constraints are set together and help to progressively design potential productive opportunities. In the case of 'life sciences' industry, a special role is played by "high-tech small and medium-sized enterprises". This population of firms appears as the central channel by which technological knowledge is created and progressively designs productive opportunities. This population can be thought of as a structural link between

academics and large pharmaceutical firms that becomes essential to transform scientific discoveries into economic activities. However, this transformation process is very uncertain and complex because of the various set of components that needed to be co-ordinated toward the same target.

The automobile industry is another interesting example to map the complexity of technological knowledge channels. What dominates the current evolution in this industry is a process of out-sourcing knowledge required by large car manufacturers. The systematic internalisation of external technological knowledge, available through the establishing of technological clusters centred upon mechanical engineering, and the complementary valorisation of internal skills have been a driving force behind the accumulation of internal knowledge and technological capability of firms. Here, the growth of large corporations seems also to be the result of specific competencies and managerial routines which have been able to keep open a variety of communication channels between the 'walls' of the company and the external environment. The corporate organisation of the production of knowledge is shifting away from the 'intramuros' model based upon well specified and self-contained research and development activities. A variety of tools are nowadays used by corporations to take advantage of external knowledge and minimise the tragedies of intellectual enclosures. Intentional participation into technological districts and technological clusters and business strategies characterised by flexible and porous borders appear to be increasingly practised by a growing number of corporations. Consequently, technological knowledge require local practices of interactive learning among partners that are not only embedded in firms (large or small). Local institutions (such as academic, educational training, or business and technical associations) are necessary to promote this local embeddedness.

Those sketchy considerations about the sectoral diversity in the production, diffusion and accumulation of technological knowledge have for solely objective to shed some lights about the intrinsic differences among productive contexts within the European industrial reality. It especially expresses the diversity in the mechanisms of generation and diffusion of knowledge at the sector level. It shows the relevance of considering the localized character of technological knowledge as an actual issue to understand industrial dynamics and, consequently, to qualify innovative behaviours of firms through a better understanding of the architecture of intrafirm and interfirm relations, that is the set of inputs and relations required to implement their activities (Metcalfe, 1995). However, those contrasting sectoral patterns put forward the difficult question of understanding the reasons for such a diversity as well as what kinds of analytical tools can be provided to qualify it.

4. HOW TO COPE WITH THE LOCALIZED CHARACTER OF TECHNOLOGICAL KNOWLEDGE ?

We have emphasised the diversity in the conditions of learning coming from the variety of technological knowledge, i.e. from differences in systemic constraints faced by productive contexts. We have shown through a few sectoral patterns the variety of this localised character of technological knowledge.

In order to cope with that variety, two central points have now to be emphasised. The one is the variety of organisational designs that perform the emergence of technological knowledge and its transformation into profitable applications. The other is the obvious diversity of communicative channels that allows for the diffusion of technological knowledge within innovation systems.

4.1 Organisational designs

Technological knowledge cannot be but firm- or context-specific. As such, technological knowledge is systemic and questions the understanding of firms' capabilities. This systemic aspect largely depends on productive contexts and the analysis requires an ability to take care of the peculiarities of those productive contexts. This questions for part the internal characteristics of a firm, that is the way by which functional and divisional operations are co-ordinated; but this also questions the way by which a firm's organisation interacts with its environment. Recent emphasis in the economic literature has made more explicit how public resources and incentives, academic infrastructures, and firms' innovative behaviours interact in a complex manner and constitute innovation systems that favour the generation and use of technological knowledge. Understanding the conditions required to the emergence of technological knowledge implies the simultaneous analysis of those three components. In other words, knowledge is organized in bundles. Strong complementarity, hence spillovers, hence increasing returns, take place only within such bundles. The difficulty comes from the fact that no unique and performing model exists; on the contrary, a huge variety of innovation systems performing new knowledge is obvious and proves the difficulty to face the role and place of technological knowledge in contemporary economies.

Therefore, there is a need for clarifying models of generating and diffusing technological knowledge. A strong challenge lies in the understanding of the variety resulting from this diversity of productive constraints faced by innovative firms.

Organisational designs used to produce and experiment technological knowledge can be characterised as a combination of productive and institutional contingencies.

Productive contingencies come from the fact that firms' organisational designs required to perform the generation of technological knowledge are moulded by productive constraints and especially by the nature and/or the history of the sectors under scrutiny. Three main requirements have to be taken into account: the fact that manufacturing a product increasingly means incorporating numerous technologies; the fact that products are becoming more complex in the sense they require increasing skills for their manufacturing to become profitable; the fact that aggregating numerous technologies increase the co-ordination needs (i.e. costs and difficulties) within the firm to engage in innovative potentialities. All those requirements largely question the characteristics of firms' organisational design as well as the understanding of the firm's innovativeness in accordance to its use of technological knowledge.

However, those productive contingencies do not completely explain why technological knowledge can become profitable and transform a "body of technological understanding" into a "body of economic practices" (see Pavitt, 1998). They need to be complemented and incorporated in a set of institutional constraints that result from the external environment faced by agents to promote and implement innovative choices. Institutional contingencies not only refer to the institutional structure of production that characterises the productive context (i.e. the complex network into which a firm is embedded, including suppliers, customers, co-operative partners, sub-contractors, etc.) but also to the institutional infrastructure that appears specific to the related industry (business and professional associations, banks, academics, etc.).

From the combination of productive and institutional contingencies results the variety of productive contexts, the diversity of innovation systems, and the relative ability to ensure a

suitable evolution of economic systems (see Quéré, 1999). Then, the localised character of technological knowledge has to be analysed through the combination of both (productive and institutional) aspects and considering the characteristics of this combination largely allows a better understanding of the variety of productive contexts aimed at favouring the viability of firms' innovative behaviours.

4.2 The variety of communication and knowledge-channels

External technological knowledge does not fall from heaven like a manna. It cannot be considered as a usual input that can be immediately internalised by firms. It requires specific absorption and 'listening' costs which depend upon the variety of codes and the number (and type) of communication channels selected by firms. The costs of the production of knowledge, including such communication costs, are lower for firms able to establish co-operative relations and access to the pool of collective knowledge made available. Appropriability also is affected. The opportunity costs engendered by the uncontrolled leakage of technological knowledge are lower, the higher are the mutuality and trust conditions in place within a group of firms. For 'given innovation costs', including research, learning and communication activities, a higher collective output can be identified. The latter makes possible the existence of external increasing returns in the production of knowledge: the larger is the number of connected firms and the larger the amount of knowledge generated.

Therefore, communication plays a central role in such a context. Communication is necessary instrumental in that it allows users and producers to identify, qualify, explore and assess the potential for knowledge externalities. As communication contributes to make knowledge externalities actually relevant from the perspective of potential users, communication

channels appear very crucial to render knowledge opportunities efficient from an economic viewpoint. While knowledge holders cannot prevent the dissipation of their knowledge, perspective users may be unable to make a good use of it.

As a consequence, the role of communication in the production of technological knowledge is emerging as an important area for theoretical and empirical research in the economics of innovation. However, the understanding of the conditions by which such communication takes place is still in progress. If a large consensus has been established about the key role of knowledge externalities in the production of new knowledge, the conditions by which those externalities appear are still to be more analysed. The variety of knowledge channels is actually puzzling. There is a central problem to be elucidated, which is the embedded character of much communicative channels. First of all, for communication to take place, at least two parties must be purposely involved: communication is inherently a collective activity. Second, the establishment of effective communication links requires long time implementation and codification of shared protocols and communication rules. Third, effective communication relies on material as well as immaterial infrastructures which can be created over time and with reciprocal consensus. Finally, in the short term, the amount and importance of the actual traffic of signals and information bits can vary greatly; in the long term, however, communication takes place and effective successful transfers of information between parties can also take place.

The conditions by which knowledge externalities appear and can be effective require to face this obvious diversity of communication and knowledge channels. In some cases, for knowledge externalities to appear and learning to diffuse, informal relationships reveal essential; in some other cases, sharing a common equipment or infrastructure seems to be its

actual characteristics; in some other cases, contractual commitments among firms appear as a necessary condition; in some other cases, the need for co-operative projects or joint-companies is made more explicit, etc. All those various contexts express the difficulty to face the localised character of knowledge and the necessity to look at the combination between organisational designs and communicative channels among firms that reveal appropriate for the same objective: the emergence and diffusion of knowledge externalities. However, the understanding of why some innovation systems reveal more effective than others is still very weak. This is why we propose to put a specific emphasis on this localised character of technological knowledge.

4.3 Toward an operational approach to cope with the localised character of technological knowledge

Emphasising the importance of the localised character of innovation processes is a means of considering the importance of the structural and sectoral diversity to which we previously refer in the creation, diffusion, and accumulation of technological knowledge.

As a consequence, to face this diversity, the essential difficulty is to figure out the peculiarities of technological knowledge as well as the related communication and knowledge channels and, consequently, to deduct from this variety the relative effectiveness of those channels in their ability to generate and diffuse technological knowledge. This can be done by organising the series of specific criteria making more explicit the productive and institutional constraints faced by firms to which we refer in mapping the contrasting characters of sectoral patterns. Those criteria can be grouped in three complementary categories: internal to the firms, external but depending on inter-firms' relationships, external but depending on institutional characteristics.

- Internal knowledge essentially refers to organisational criteria and includes factors such as the characteristics of internal R&D and its related use in the production process, the type of firms' organisational designs and their ability to favour internal learning, the internal technological infrastructure (intranet capabilities and, more largely, any other I&T facilities)

- External knowledge related to products' requirements essentially includes the formal and informal relationships that reveal necessary for a suitable organisation of the industry. This refers to the technological peculiarities such as the multitechnology characterisation of the sector products, the role of capital equipment and physical infrastructures. This also refers to individual mobility as well as the importance of users/producers relationships for the evolution of demand, the importance of knowledge intensive business services (KIBS) and, more, largely, the appropriability conditions of sector-specific technological knowledge. A specific aspect of external knowledge lies in the growing importance of the internet interface in its ability to favour the acquisition and diffusion of technological knowledge.

- External knowledge related to institutions refers to 'environmental' criteria such as the importance of public institutions for the evolution of demand (direct support, regulatory framework), the relative importance of knowledge-sector characteristics (tacit/codified-individual/collective-generic/specific), the importance of academics and of related institutions in the generation of technological knowledge and, more largely the type and importance of knowledge externalities.

This classification helps to cope with the diversity and the underlying complexity in the mechanisms driving the working of technological knowledge and its implementation into new productive activities.

This complexity is basically due to the multitechnological character that sectors' patterns exhibit, where a variety of coexisting and partly complementary knowledge is identified. Knowledge in fact can be conceived as a single folder of a variety of specific and localised knowledge, each of which has a specific context of application and relevance. However, strong complementary effects exist among technological knowledge and help making the folder a single container. In a monotechnological context, direct competitors can make a rival use of proprietary knowledge and reduce its economic value for original holders. In a multitechnological one instead, perspective users are not direct competitors and external knowledge is an intermediary input which, after proper recombination and creative use, becomes a component of the localised production process of new knowledge. Local cumulativeness and indivisibility are clearly important attributes of technological knowledge: new knowledge is built upon previous one and indivisibility is relevant both diachronically between old and new technologies as well as horizontally among a -limited- variety of new technological knowledge being introduced at each point in time.

Therefore, technological knowledge is crucially embedded in local contexts and it is important to qualify this localised character. Specifying the previous criteria helps to characterise the systemic dimension of this localised embeddedness of technological knowledge in that it offers a sort of 'structural' map aimed at ordering the diversity of technological knowledge characteristics and infer the conditions by which innovation occurs, becomes feasible and diffuse within the production system. From such a mapping, it becomes

possible to identify the main characteristics of the communication and knowledge channels that reveal effective, as regards the productive and institutional constraints encountered by firms' innovative behaviours.

This analysis contributes to better identify technological knowledge as a collective activity where potential knowledge externalities, because of the active implementation of communication activities, can be shared and become the source of major increasing returns. Such a collective character, however, is actually workable only when localised within circumscribed regional and/or technological environments. The costs of communication and the fall in the positive effects of knowledge externalities associated with dissipation driven by the increase of distance and heterogeneity among users and producers limit the scope of fruitful interaction.

5. POLICY CONCLUSIONS

Discussion about the localised character of technological knowledge is correlated but also largely contrasts with the current debate on the working of the learning economy. Our analysis provides an attempt to link questions related to the learning conditions of an economic system not directly to a theory of knowledge by itself but to the co-ordination issues that underlie a more suited theory of innovation.

This shift in the analysis takes particularly sense when considering policy implications and recommendations. The fact that the conditions required for the generation and use of technological knowledge cannot be but systemic and localised in the aim is deducted from the intra as well as inter-sectoral diversity of institutional designs favouring the generation and the profitable use of technological knowledge.

Complex characteristics of technological knowledge justify the need for considering centrally the systemic character of policy-making. Science and technology policies, industrial policies, and competition policies are all components influencing the working of technological knowledge. They need to be effectively articulated in order to perform their capability to support firms' innovative behaviours. The analysis of the localised character of technological knowledge is of a central help to understand interactions among those complementary policy aspects as well as to discuss the scope of coherent innovation systems that the interplay among policy decision-making and firms' or sectors' evolution can design.

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