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THE GOVERNANCE OF INTERACTIVE LEARNING WITHIN INNOVATION SYSTEMS

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ABSTRACT

The generation of new technological knowledge is the result of a variety of interactions: market transactions are only a subset of a much wider flow of knowledge interactions and technological communication. Specific governance mechanisms are necessary to make technological interactions and technological communication possible. Specific governance mechanisms emerge under the influence of the specific contingencies of the types of knowledge, products, markets, organization of firms and institutions involved.

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1. INTRODUCTION

An important shift in the economics of innovation has taken place after the new understanding of the key role of the economics of the distribution of knowledge. Next to the economics of the production of knowledge, the economics of the distribution of knowledge has emerged as a distinct area of investigation dedicated to understanding the role of external knowledge and interactive learning in the production and usage of new knowledge. Each bit of technological knowledge is not only the end result of a process of generation but also the input for the generation of new bits.

In the economics of the production of knowledge the low levels of appropriability and excludability of technological knowledge have been regarded for a long time as a major source of market failure. Low appropriability and excludability qualified technological knowledge as a quasi-public good. This quasi-public good character provided a clear case for under investment and poor division of labor. The structure of incentives for agents was not apt to generate appropriate levels of allocation of resources in the generation of new knowledge. The intrinsic limits to tradability would undermine the division of labor and hence limit the advantages from specialization.

In this context, three institutional devices have traditionally been considered appropriate to reduce the welfare losses: the corporation, the public funding of research and the intellectual property rights. Barriers to entry and monopolistic competition would provide to corporations ex-ante appropriability, reducing the risks of leakage and imitation. In turn large price-cost margins for corporations would provide sufficient internal financial markets and hence competent decision-making with the liquidity and information necessary to fund new promising research activities. Public funding, mainly to universities and public research laboratories, would increase the basic levels of production of scientific knowledge and hence push eventual top-down applications in terms of technological knowledge. Intellectual property rights finally would increase sheer appropriability, hence make trade in technological knowledge easier and induce higher incentives and investments in the generation of new knowledge.

In the economics of the distribution of technological knowledge, the understanding of the key role of knowledge as an essential facility for the production of new knowledge provides a different framework of analysis (Stephan, 1996; Foray, 2001). Each bit of knowledge is an essential input in the multiplicative relationship with other factors, such as competence, talent and skills which leads to the generation of new knowledge. Each bit of knowledge is complementary to other bits of knowledge and its availability is conditional to increasing the chances for further advances (Antonelli, 1999; 2001)

In this context, the understanding of the specific governance 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, productive and organizational context into which firms' conducts and strategies are embedded. It requires a deeper understanding of how fundamental imbalances in resources induced by any process of change for firms activities, in product and factor markets as well as in internal markets, are managed over time and eventually coordinated IN A SUITED MANNER.

The governance of the intrinsic complementarity among agents in the identification of appropriate technological solutions, as guiding posts for the formation of effective coalitions, is key to understanding such dynamics. A dynamics where competition often follows sequentially co-operation in selecting and assessing the basic technological requirements and interfaces (Bijker, 1987; Quéré, 2000).

This paper focuses the analysis ON the coordination mechanisms of innovation ystems where the distribution of knowledge plays a key role. This analysis impinges upon the systemic and localized understanding of technological knowledge as provided in section 2. Section 3 explores the variety of coordination mechanisms at work within innovation systems and provides a rationale for their assessment. The key role of the governance of innovation systems is stressed in the conclusions.

2. THE LOCALIZED UNDERSTANDING OF TECHNOLOGICAL KNOWLEDGE

This paper elaborates upon a specific understanding of knowledge, defined as 'localized technological knowledge'. Localized technological knowledge is more than technological resources in that it incorporates the specific ability to organize, 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. Localized technological knowledge incorporates the distinctive and dedicated flow of interactions that a company has to manage both with respect to its internal components and with its productive environment. The latter of course refers to other firms 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 organizations such as business associations and science and technology institutions. Taking all this set of components into consideration appears as a necessary condition to the understanding of the localized character of technological knowledge, i.e. to the understanding of the conditions companies are facing to ensure the evolution of their activities. The generation and distribution of technological knowledge and the introduction of technological innovation have a strong systemic character because of the key role of the localized interactions among learning agents (Gibbons, Limoges, Nowotny, Schwarzman, Scott and Trow, 1994; David, 1998).

Such interactions are not fully cleared by the price mechanism: as such, externalities and spillovers play a key role. Effective distribution and scope for recombination however can take place only when absorption costs are low and communication among agents is actively sustained in time. The variety of learning agents in terms of learning opportunities and incentive mechanisms is also a key factor: effective innovation systems include manufacturing firms, service firms, universities and research centers, active financial actors and in general a myriad of specific actors specialized in complementary roles. In sum, localized technological knowledge is more and more viewed as the result of the repeated and dynamic interactions of agents which are embedded in a variety of specific and highly idiosyncratic constraints (Antonelli, 1999 and 2001).

Systemic interactions are characterized by relevant dynamic features, because of the role of feed-backs. In other words, the generation and distribution of knowledge become specific, depending on the local conditions into which this knowledge is embedded. No mistake here: this 'localized' character of knowledge does not mean that it refers exclusively to a geographical meaning. The localized character of knowledge has in fact to do with the architecture of intrafirm and interfirm relations, that is the set of inputs and relations required to implement their activities (Metcalfe, 1995).

Our understanding of the localized character of technological knowledge and of technological change impinges three well distinct and yet overlapping basic notions.

A first set of arguments stems from the analysis of the role of learning and irreversibility. Technological knowledge can be introduced only in the technical areas that firms practice and are expert of. All changes in demand and factor prices can induce a localized technological change. Firms move along technological paths defined by the irreversibility of relevant portions of their assets and the related switching costs, the original endowments, the localized learning and generation of knowledge and new technologies. In turn such technological paths cluster around the common endowment of industry-specific and region-specific sets of technological opportunities, knowledge infrastructure and communication channels (Antonelli, 1995; 2001).

Second, knowledge is organized in bundles. Strong complementarity, hence spillovers, hence increasing returns, take place only within such bundles. In turn, many such bundles are regionally concentrated and evidence expressed the existence of local spillovers (think of the Silicon Valley or Torino: all an industry, respectively the automobile and the software, concentrates in a few squared miles). In other words, what matters is the near-decomposability of knowledge which assumes a strong technical and regional dimension (Simon, 1962; 1969 and 1982).

The third set of arguments is elaborated on the analysis of the role of external knowledge and absorption and communication costs (Griliches, 1992; Stiglitz, 1997; 1998). As Stiglitz (1999a&b) puts it, the generation of new technological knowledge relies upon the capability of agents 'to scan globally and reinvent locally' combining new generic knowledge with the specific idiosyncratic product, market and technical conditions of application into which each agents operates. The generation of new technological knowledge by each agent relies systematically upon its ability to access, retrieve, understand and use external knowledge.

External technological knowledge however does not fall from heaven like a manna. It cannot be considered as an usual input that can be immediately acquired in the market place and internalized by companies. It requires specific search, identification, transaction, acquisition, absorption and 'listening' costs which depend upon the variety of codes and the number of communication channels selected by companies. This is why the localized character of technological knowledge matters.

A quote from the recent remarkable book by Richard Caves may help to make clear this point: "Economists usually assume that the competitive firm's primary concern is to protect proprietary knowledge from appropriation by would-be raiders. Yet the firm's better strategy may be to tolerate extensive leakage of knowledge from its corridors and conference rooms, in exchange for keeping its own receptors tuned to knowledge seeping from competing firms. Extensive swapping of information between employees of competing firms takes place in many high-tech activities, as indeed job-hopping from firm to firm." (Caves, 2000: 367). In other words, the costs of the production of knowledge are lower for firms able to establish co-operative relations and access to the bundles of collective knowledge (Richardson, 1960 and 1972; Rosenberg, 1976; Knorr Cetina, 1981; von Hippel, 1988).

Technological communication plays a central role in such a context. Communication is a necessary instrument in that it allows users and producers to identify, qualify, explore and assess the potential for knowledge externalities. As communication contributes to make knowledge complementarities actually relevant for potential users, communication channels are 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 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 complementarities in the production of new knowledge, the conditions by which those complementarities materialize are still to be fully grasped (David, 1998).

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. Thirdly, effective communication relies on material as well as immaterial infrastructures which can be created over time and with reciprocal consensus. Finally, appropriability regimes play a key role: agents are well aware of the risks of uncontrolled leakage of their know how. The trade-off between the advantages of the access to external knowledge and the costs of the loss of appropriability varies according to the mechanisms of governance at play.

The conditions by which knowledge complementarities materialize and can be effective from an economic viewpoint require to analyze the coordination of communication channels and knowledge interactions. In some cases, for knowledge complementarities to materialize informal relationships reveal essential; in other cases, sharing a common equipment or infrastructure seems to be the actual device; in other cases, contractual commitments among companies appear as a viable condition; in other cases, the need for co-operative projects or joint-companies is made more explicit. These various contexts confirm the need to look at the combination of specific contingencies that shape the governance of the learning interactions and communication processes that make possible the emergence and distribution of technological knowledge (Williamson, 1975, 1988 and 1996).

This can be done by organizing the series of specific criteria making more explicit the productive, organizational and institutional constraints faced by firms engaged in the generation and use of new technological knowledge. The empirical evidence, across sectors and corporations, suggests that there are several governance mechanisms at play. Such variety in turns seems associated with the specific characteristics of knowledge, the complexity of productive requirements, and the ability to manage interfirms and intrafirms relationships. In that respect, we can learn from the large literature available and elaborate upon the sectoral and national differences on the way by which firms are facing the governance of the production of technological knowledge (Teece, 2000).

3. THE GOVERNANCE MECHANISMS: HOW TO IMPLEMENT TECHNOLOGICAL COMMUNICATION WITHIN INNOVATION SYSTEMS

Because of the complexity of the interactions involved in the implementation of technological knowledge, and the limited role of price mechanisms to clear such interactions, the analysis requires to focus on innovation systems as governance mechanisms and organizational modes of coordinating economic activities aimed not only at the generation of technological knowledge but also at its distribution and its transformation into profitable applications. A central point emerges here: the diversity of governance mechanisms that allow for the distribution and recombination of technological knowledge within innovation systems (Williamson, 1975, 1988 and 1996).

Technological knowledge cannot be but firm- and context-specific. As such, technological knowledge is systemic and questions the understanding of firms capabilities. This systemic aspect largely depends on the specific characters of technological knowledge itself and on products and markets contexts and the analysis requires an ability to take care of the interplay between such peculiarities. In turn this questions both the internal characteristics of a firm, that is the way by which functional and divisional operations are coordinated; and the way by which a firms organization interacts with its environment (Freeman, 1991; Amendola and Gaffard, 1994),.

Recent emphasis in the economic literature has made more explicit how public resources and incentives, academic infrastructures, and companies innovative behaviors interact in a complex manner and constitute innovation systems that favor the generation and use of technological knowledge. As such, the understanding of the conditions required for the emergence of technological knowledge implies the simultaneous analysis of those three components. 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 (David, 1993; 1994 and 1998).

Organizational designs and governance mechanisms used to produce and experiment technological knowledge can be considered the result of a combination of product and market, firm, knowledge and institutional contingencies. The variety of governance mechanisms, the diversity of innovation systems, and their relative ability to ensure a suitable evolution of economic systems stem from the combination of these different contingencies.

Product and market contingencies mark the generation of technological knowledge. Product complexity plays here a significant role. The aggregation of numerous technologies and skills increases coordination costs within the firm in order to generate and take advantage of innovative potentialities. The larger is the product complexity and the larger is the viability for interactive learning in intermediary markets. Second and most important, each sector is characterized by specific market forms ranked from quasi-perfect competition to oligopolies, from monopolistic competition to actual monopolies. The height of barriers to entry in general is a key factor in assessing the organizational design of innovation systems: the more difficult is entry and the smaller are the risks of uncontrolled leakage and imitation. When barriers to entry, even in small market niches, are high, cooperative behavior and interactive learning are more likely to take place. Product and market contingencies shape the mechanisms of governance of the interactions that are conducive to the generation and distribution of new technological knowledge.

Product and market contingencies however do not completely explain why technological knowledge can become profitable and transform a 'body of technological understanding' into a 'body of economic practices'. They are obviously highly dependent from firms' contingencies. the latter are traditionnally asssociated in managerial issues along the penrosian conception of the growth of the firm (Penrose, 1959). However, firms' contingencies are more than managerial ones. Firms differ widely, even within sectors, in terms of organizational structure, systems of incentives, degree of decentralization and forms and procedures in decision-making. Firms can activate internal markets and design internal structures of incentives that stimulate the search, accumulation and eventual use of new technological knowledge: dynamics efficiency wages and internal labor mobility play an important role in this context. At the other extreme high centralized bureaucratic structures may be better able to direct the flow of investments and focus the new business opportunity, but less able in exploring new directions and hence less able to sustain the accumulation of technological knowledge (Aoki, 1984).

One peculiar characteristics in the current working of innovation systems lies in the need for considering that product, market, and firms' contingencies have to be complemented by the characteristics of knowledge itself in order to make more understandable how governance mechanisms work. Knowledge contingencies consist in the specific characteristics of technological knowledge in terms of natural appropriability, horizontal and vertical cumulativity, unpredictability. Technological knowledge can be more or less appropriable according to the levels of natural excludability on the supplier side and on the levels of tacitness and stickiness on the users' side, i.e. the efforts that are necessary to acquire, reproduce and use it. Technological knowledge can be embedded in organizations more than in skills. In the former case technological knowledge has high levels of information impactedness, consist of complex procedures. In the latter case instead personal knowledge, embodied in individuals, plays a stronger role. Technological knowledge is horizontally cumulative when it applies to a variety of products and processes and each new application has positive effects on incremental ones. General purpose technologies exhibit high levels of horizontal cumulativity. Technological knowledge is vertically cumulative when it is complementary and coherent with existing portions of knowledge and it can be added so as to increase its effects and scope of application.

Additional complexity is due to the multi-technological character that many industrial applications exhibit, where a variety of coexisting and partly complementary knowledge is identified. Knowledge 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 complementarities exist among technological knowledge and help making the folder a single container. in a mono-technological context, direct competitors can make a rival use of proprietary knowledge and reduce its economic value for original holders. In a multi-technological 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. The unpredictability of the possible outcomes of research efforts also plays a major role. Monitoring costs increase with the levels of unpredictability. Formalized procedures, such as contracts and joint ventures to implement interactive learning can be harmed by high levels of unpredictability: The parties have greater problems to agree upon the terms of the contracts.

Actual conditions for appropriability of technological knowledge play an important role in assessing the selection and implementation of governance mechanisms. Appropriability of technological knowledge can be enforced by means of secrets, time lags and intellectual property rights. When secrets and time lags matter, transactions and interactive learning are risky for high costs of opportunistic behavior. An effective property right regime favors instead interactions among learning agents

Intellectual property rights do increase effectively appropriability when the technological knowledge has a strong codified content and well defined context of application. Intellectual property rights have been mainly designed to increase appropriability, rather than favoring the distribution of technological knowledge. Enforcement, breadth, duration and assignment procedures of patents however do have a role from a specific distribution viewpoint. Patents increase tradability and hence distribution and division of labor in the generation of new knowledge: weak property rights may induce the holders of relevant bits of knowledge to rely upon secrets with a sharp reduction in the circulation of information. Broad patents however, granted with a large scope, can increase litigation and transaction costs and hence reduce circulation and tradability. Duration and derivative rights increase the confidence of patents holders and reduce opportunistic free-raiders. The right of exclusive use is coming more and more under question and the tradition of non-exclusive use of copyrights is regarded with increasing favor. Finally patents assigned with first-to-invent procedures reduce the risks of litigation, on the opposite, first-to-file procedures favor blind inventions and rush to patenting. They act more as signaling devices about new greenfield technological opportunities than effective property rights. Although the design of intellectual property rights and especially exclusive rights granted to patent holders have an important effect on tradability, the actual transactions of technological knowledge seems implemented by complementary long term contracts. innovation systems do differ widely across countries according to the specific design of the intellectual property right regimes. In turn the role of patents as an appropriability-enforcing mechanism vary across technologies, according to the scope for horizontal and vertical cumulativity (Oxley,1999).

The specific character of knowledge contingencies stresses the importance of the contextualization of knowledge that is not only reducible to the intellectual property rights regimes. In order to understand the actual working of innovation systems, a discussion about the institutional context into which firms are embeeded is also necessary. Considerations about the set of institutional constraints that result from the external environment faced by agents to promote and implement innovative choices have to be provided. Institutional contingencies not only refer to the institutional structure of production that characterizes the productive context (i.e. the complex network into which a firm is embedded, including suppliers, customers, co-operative partners, sub-contractors, labor markets) but also to the density and complexity of the institutional infrastructure that appears specific to the geographic, industrial and national context such as business and professional associations, academic and public research institutions; legal and judiciary traditions.

The identification and specification of that overall set of contingencies (and the related previous criteria) help to characterize the systemic dimension of the production and distribution of localized technological knowledge in that it offers elements of a “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 governance mechanisms that reveal effective, as regards the constraints encountered by firms innovative behaviors.

4. THE GOVERNANCE MECHANISMS: HOW TO ORDER THE DIVERSITY OF INNOVATION SYSTEMS

The architecture of governance mechanisms at play in each specific circumstance can be thought of as the outcome of a discovery process aimed at coping with the diversity and the underlying complexity in the mechanisms driving the working of technological knowledge and its implementation into new productive activities. The previous characterization of innovation systems makes it possible to emphasize the key role of the dedicated interactions between learning agents both within and among firms, and the essential role played by communication channels, that is the active participation of both 'talkers' and 'listeners' in making technological knowledge available. Such an analysis contributes to better identify technological knowledge as a collective activity where potential knowledge complementarities, because of the active implementation of communication activities, can be shared and become the source of major increasing returns.

The analysis of the empirical evidence available on innovation systems makes it possible to identify, next to innovation systems based upon the key role of corporations and public funding, four basic and complementary types of coordination mechanisms at work: A) Innovation systems where geographic space play a key role; B) Innovation systems centered upon knowledge intensive business services; C) Innovation systems centered upon financial markets; D) Innovation systems based upon long term contracts. Let us analyze them in turn.

A) Innovation systems where geographic space play a key role

Geographic proximity plays a key role when transaction and communication costs are effectively reduced by repeated interactions and trusts, enhanced mobility of human capital and frequent user-producer interactions. Geographic space acts as the basic governance mechanism in that it reduces both transaction and communication costs because it makes easier continuity in relations and contributes the basic commonality in languages and codes. Geographic space seems to become an effective governance mechanism when technological knowledge has a large generic content and as such can be applied to a variety of products and processes. Often many such applications are in turn complementary both in production and in use. The advantages of both horizontal and vertical division of labor can be easily exploited by a variety of complementary actors, provided common rules of reciprocity and symmetric access to the production of collective knowledge take place.

Cities are loci where coordination mechanisms among agents seem a priori easier to be established because of the physical proximity. However, empirical evidence also shows how some cities are more effective than others in favoring local innovation and growth. The variety of communication channels seems to us a distinctive feature of cities that largely contributes to the explanation of the related variety in economic performance.

Cities exhibit at least two categories of communication channels that give them a unique character. One includes formal communication channels provided by cities' infrastructures. The other informal communication channels. Cities increase the probability of meeting informally complementary resources directly through professional associations & clubs and indirectly through daily life services. Cities are nodes of communication and providers of knowledge externalities in a dense networks of market transactions and relationships. Cities allow for the immediate availability of a huge range and variety of resources. Cities provide a conducive context for technological complementarities to be grasped especially when technological knowledge is mainly embodied in human capital. Cities in fact favor the mobility of human capital across firms and industries: labor markets are more effective when physical distance is not a constraint to labor mobility. Cities provide the context into which innovation systems can be centered upon academic infrastructure. Universities play a key role as driving factors in the production and distribution of new technological knowledge. The lags and delays which characterize the relations between the production, distribution and effective use of knowledge can be reduced by the direct involvement of academics in business undertaking. Such direct involvement can take two forms: the entry of academics into business life with technological entrepreneurship and the direct role of universities as providers of knowledge intensive business services (Geuna, 2000).

Cities, including the so-called technological districts, emerge as viable governance mechanisms especially when and where technological knowledge is mainly the result of learning processes and as such is mainly embodied in human skills. High levels of knowledge complementarity and communication costs for perspective innovators play a key role in assessing the viability of this governance mechanism. The density of the institutional environment and the high levels of knowledge externalities spilling in the atmosphere also help. Monopolistic competition among firms able to defend their own market niche and, at the same time, to take advantage of network externalities in both supply and demand helps barter relations and hence the implementation of this governance mechanism. The advantages of proximity however are most effective in terms of mobility of human capital across firms and sectors. Cities emerge as viable governance mechanisms when they provide a rich set of institutions that are conducive to implement and favor effective communication channels fevoring the coevolution of the demand and supply for specific skills and specific areas of competence and expertise. (Clark, Feldman and Gertler, 2000).

High levels of vertical and horizontal cumulability of technological knowledge are the cause and the consequence of geographical agglomeration. Technological knowledge is typically industry specific and as such it is embedded in specific procedures and codes which are specific to a well defined range of technologies and innovation routines. Relevant internal coordination costs limit the innovative capabilities of large corporations because of the variety of bits of complementary knowledge which is necessary to coordinate. Centralized decision making reduces flexibility and the size of technological portfolios.

Clearly firms contingencies play a major role in assessing the viability of this governance mechanism together with low appropriability regimes of technological knowledge, high barriers to entry in the product markets and high levels of product complexity. Product contingencies matter together with demand conditions. Cities and technological districts are appropriate governance mechanisms when demand is uncertain and firms prefer to spread sunk costs into a variety of specific processes and products.

Innovation systems based on geographical space can complement corporations. Within cities and technological districts in fact large corporations can guide the generation and distribution of technological knowledge by means of networks of complementary actors where users-producers interactions are coordinated and implemented by a central hub.

C) Innovation systems centered upon knowledge intensive business services (KIBS).

Technological interactions can also be embodied in knowledge intensive services. The external provision and the outsourcing of technological knowledge takes place by means of trade in services that embody bits of technological knowledge. Knowledge is accumulated and provided by KIBS to a variety of users. KIBS specialize in the key role of interface between bundles of generic knowledge and a variety of specific and idiosyncratic applications. Here, knowledge has the strong characters of both industry and region specific quasi-private good. Application is sufficiently complex and time-consuming to provide higher appropriability conditions. In turn, KIBS can become the engines of accumulation when and if they can both apply generic knowledge to specific conditions and generalize new generic knowledge out from the specific recollection of experience and localized learning accumulated in each specific context of application. In this context, innovation systems can be centered upon actual new markets for knowledge when the provision of services is complementary and indivisible from knowledge interactions.

This governance mechanism relies upon the interplay between generic and specific knowledge. The complementarity between generic knowledge and the specific and idiosyncratic contexts of application play a key role in assessing the viability of this governance mechanism. The generation of each specific bit of new technological knowledge requires the use of large amounts of generic knowledge which is itself the result of long term accumulation and implementation. The competitive provision in the market place of knowledge intensive business services makes it possible to combine low levels of excess capacity in the use of generic knowledge and hence low average costs of specific applications and localized, tailored innovations. The emergence of an actual market for technological services makes it possible to achieve higher levels of division of labor and specialization. At the system level, moreover, the identification of the correct amount of resources to be allocated into the production and distribution of technological knowledge becomes easier. At this system level, it is clear that this governance mechanism provides the advantage of increasing returns, stemming from economies of density and cumulability, yet in a competitive context.

C) Innovation systems centered upon financial markets.

The direct embodiment of technological knowledge into a financial asset is an important governance mechanism to make the access to external knowledge and knowledge interaction at large possible. Technological knowledge is not traded per se, but as a key asset of a new company whose shares can be traded in the market place. This device has many advantages such as the distribution of risks among a variety of investors, the reduction in opportunism due to the active involvement and participation of the innovators in the incubation. Financial markets play a key role as filters and screeners of a variety of newcomers and business ideas. The admission to the Stock Exchange implies that a specific assessment has taken place and that each such newcomer in the Stock Exchange embodies a valuable piece of new technological knowledge. Venture capitalists invest and initial public offerings take place only when a variety of specialized experts have expressed a positive assessment on the specific undertaking. Such market signaling makes knowledge accumulation possible because it makes easier for perspective investors to direct their funds and even for customers to better assess the quality of the new products. Financial markets provide a unique opportunity to acquire bits of knowledge embodied into start-ups and high-tech ventures and recombine them so as to generate new technological knowledge which is directly relevant for the eventual introduction of successful innovations. In so doing financial markets provide the viability for ‘mix and match’ strategies, built upon mergers, acquisitions and spin-offs finalized to build a set of complementary knowledge assets and competencies.

This governance mechanism seems to apply when technological knowledge is embedded in specific applications and complementary unit of knowledge which are built into organizations and as such are difficult to imitate and even to leak because they are not easy to understand and reproduce. Free riding is impeded by the high levels of product complexity and high levels of information impactdeness built into organizations. Venture capital and the floatation of initial public offerings become an effective tool to reduce the high risks of credit rationing traditionally associated with the provision of financial resources to innovative activities by financial systems characterized by a strong role of banks and hence high levels of intermediation (Lerner, 2001).

D) Innovation systems based upon long term contracts.

Technological knowledge can be traded in the market place provided a number of institutional devices are implemented. Long term implicit contracts play a key role as enforcing devices. The low levels of specification – an essential aspect of implicit contracts- are balanced by the long time duration of the contracts. The parties are basically unable to specify all the possible outcomes of the knowledge interactions and of the technological communication channels they agree to establish. In the long term however the parties can learn from the interaction and assess the relationship. Time becomes a complement of the market transaction so as to make the coordination of the knowledge interaction possible. Such contracts can take two basic forms: technological clubs and licensing.

Firms agree to open knowledge interactions and technological communication within technological clubs that are associated in innovation systems. Actual and formal memberships into specific institutions designed to complement the exchange of technological knowledge is an important governance mechanism. The identification of the specific rules which enforce appropriability regimes and substitute for trust is the key factor at play. Internal coordination costs may arise as well as relevant entry and exit costs. Transaction and communication costs are basically reduced by ownership and administrative governance provided by central organizations. Low levels of natural appropriability of technological knowledge and high costs of enforcement of intellectual property rights make internal coordination and monitoring costs comparatively lower.

Firms can accept to transfer their knowledge to third parties either unidirectionally or bidirectionally within the context of licensing and swapped contracts. The combination of the trade in services and knowledge interactions is the distinctive feature here. The parties agree to allow the knowledge interactions provided the exchange of knowledge embodied in patents or know how is implemented by the actual delivery of services and technical assistance. Such services in turn enhance the control on the use of the knowledge which has been transferred. Technical assistance is also and in some cases mainly a tool to reduce information asymmetries upon the eventual developments of a given unit of knowledge. Technical assistance makes it possible to enforce derivative property rights especially when licensing is crossed (Arora, Fosfuri and Gambardella, 2001; Guilhon, 2001).

Long term implicit contracts are viable mechanisms of governance of knowledge interactions and technological communication when the time horizon is long enough to play a role as the basic complementary coordination mechanism. The standard price mechanism can work only if a number of complementary institutional devices are enforced and the parties can sequentially reassess their obligations. In turn, the length of the time horizon is influenced by the entropy levels in the product markets and in the technological knowledge itself.

5. CONCLUSIONS

A substantial consensus is emerging among innovation economists on the systemic features of the generation and distribution of technological knowledge and introduction of technological change. The innovation system approach makes it possible to understand the complexity of interactions which lead to the accumulation, generation and distribution of new technological knowledge and to the eventual introduction of technological innovation. Markets and the price mechanisms are able to clear only a limited portion of such interactions. Traditional governance mechanisms such as the public funding of the academic system and of research activities conducted by the business sector and the key role of large corporations are now, more and more paralleled by other governance mechanisms where small and medium size firms and local government can play an active role.

The system of innovation approach makes it possible to appreciate the complexity of interactions which are necessary to generate new knowledge: market transactions are only a subset of a wider flow of knowledge interactions and technological communication. Specific structures of governance mechanisms appear as institutions which make technological interactions and technological communication possible. Such governance mechanisms emerge under the influence of the specific contingencies of the types of knowledge, products and markets, and organization of firms and institutions involved in such learning interactions.

The analysis of the combination of such contingencies has made it possible to identify four basic types of coordination mechanisms at work: A) Innovation systems where clustering in geographic space plays a key role; B) Innovation systems centered upon knowledge intensive business services; C) Innovation systems centered upon financial markets; D) Innovation systems based upon long term contracts.

These modes of governance of accumulation and distribution of technological knowledge are specifically apt to deal with interactive learning. They complement and partly substitute the traditional coordination modes such as the large corporation, the intellectual property rights and the public funding.

These four modes should be regarded as ideal types more than self standing empirical patterns. Much empirical research in the innovation system approach has made it possible to appreciate the variety of specific governance and coordination mechanisms at work stemming from different mix of the four basic types identified. Innovation systems, conceived as architectural structures of governance mechanisms, vary according to the key elements at play, the dynamics of the systems themselves and the structures of the relations at work within each system. Much variety among innovation systems seems to stem from the variety of modes of coordination of the elements of the systems. In turn the structure of the innovation systems and their dynamics seem to reflect the modes of coordination. The complex and transitive relationship between the structure and the dynamics of innovation systems and their modes of coordination seems to become a central issue. The modes of governance of interactive relations that lead to the generation and actual use of technological knowledge are key institutional factors in assessing the innovation capability of an economic system.

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