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TECHNOLOGICAL KNOWLEDGE AND THE THEORY OF THE FIRM: THE ROLE OF IDIOSYNCRATIC FACTORS

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TECHNOLOGICAL KNOWLEDGE AND THE THEORY OF THE FIRM: THE ROLE OF IDIOSYNCRATIC FACTORS [1]

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ABSTRACT. This paper elaborates a theory of the firm that combines the intuitions of Edith Penrose with the analysis of localized technological knowledge. The analysis of the characteristics of knowledge indivisibility and of key role of the intentional strategy of firms, induced by competition forces and the mismatch between beliefs and actual market conditions integrates the basic ingredients of the resource-based theory. The firm is viewed as a learning agent that induced by market forces and building upon learning processes, elaborates and implements intentionally strategies of knowledge generation. These strategies include the necessary identification of the external sources of complementary technological knowledge. Internal learning, in fact is a necessary, but not sufficient condition for the generation of new knowledge. The analysis of the conditions for the intentional generation of technological and organizational knowledge becomes crucial. Such conditions, in fact, are not only internal to the each firm but also and mainly external to the firm. In this context, the governance approach elaborated by Oliver Williamson is applied to the analysis of the access to external knowledge. The analysis of the combined effects of internal learning and external knowledge cum intentional decision-making provides key inputs to understanding the path dependent and idiosyncratic features of the growth of the firm.

KEY-WORDS: KNOWLEDGE; THEORY OF FIRM; PATH DEPENDENCE.

JEL CLASSIFICATION: O31

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1. INTRODUCTION

Recent advances in the economics of knowledge make possible important progress in understanding the key role of idiosyncratic path dependence dynamics in the theory of the firm. The merging of the resource base theory of the firm with the transaction costs approach has shown its heuristic advantages in understanding the basic conditions for the existence of the firm and the logic of inclusion and exclusion of different activities within the borders of the firm for given levels of competence and knowledge. A further and essential step is now necessary to understand the dynamic conditions that lead to the generation of new knowledge**.** This step can be done by combining the line of analysis articulated by Penrose (1959) with the inducement approach and the key role of knowledge indivisibility to explaining the generation of technological change and technological knowledge. In this paper the role of intentional strategies and external knowledge, in the generation of new knowledge is stressed and opposed to automatic, internal learning in section 2. Section 3 highlights the role of external knowledge. Section 4 elaborates the implications in terms of the idiosyncratic character of technological knowledge. The conclusions summarize the main results of a dynamic theory of the firm when the role of the generation of localized knowledge is appreciated.

2. FROM AUTOMATIC LEARNING TO THE INTENTIONAL GENERATION OF NEW KNOWLEDGE

The resource-based theory of the firm has grown as a development and an application of the economics of learning. The path breaking contribution of Edith Penrose has actually paved the way to the economics of learning: the founding contribution of Kenneth Arrow (1962a) follows, as a matter of fact, the 1959 book by Edith Penrose. A wave of contributions has subsequently explored the dynamics and the characteristics of learning processes, such as learning by doing and learning by using and learning by interacting, has led to the identification of the firm as the primary locus of the generation of new technological knowledge. The generation of technological knowledge can be considered as the distinctive feature of the firm: the firm exists, beyond and actually before the production function, as the institution able to generate technological knowledge and apply it to the production of goods (Penrose, 1959; Arrow, 1962a; Langlois and Foss, 1999).

In the resource-based theory of the firm, the generation of technological knowledge is regarded as the distinctive feature of the firm. The firm does not coincide with the production function and cannot be reduced to a production function because its essential role is the accumulation of competence, technological and organizational knowledge and the eventual introduction of technological and organizational innovations. From this viewpoint the firm precedes the production function: the technology is in fact the result of the accumulation of knowledge and its application to a specific economic activity. Technological knowledge can be considered the primary output of the firm. The resource base theory of the firm however presents learning as an automatic process, the joint product of current activities and assimilates knowledge to learning. Little attention is given to the context into which learning takes place and especially to the analysis of the conditions and motivations: learning seems to coincide with new knowledge.

Learning indeed is one of the basic sources of new technological knowledge. As such it exerts a strong and clear effect in terms of a definition of the cognitive space into which each firm can expand its current technological base. As a consequence the new technological knowledge generated by each firm is constrained within the proximity of its current activities. In other words, learning exerts a powerful localizing effect, which limits the spectrum of possible discoveries. At the same time however the generation of new knowledge can take a wide variety of possible directions leading towards the introduction of either product or process innovations, impinging upon the specific form of learning that is actively implemented. Learning, by definition takes place while performing the current activities which in turn are highly differentiated according to whether firms rely more on learning by doing, or learning by using, or learning by interacting with customers or suppliers, and in each of the many specific sub-activities which are comprised within the current boundaries of each firm at each point in time.

Here the complementarity between the theory of the firm developed by Edith Penrose and the notion of localized technological change originally articulated by Joseph Stiglitz and Anthony Atkinson and Paul David respectively in the context of the theory of production and the early economics of innovation and technological change is most clear.

A number of important qualifications however are necessary in order to build upon the overlapping between these two strands of economic theory. Learning in fact is a necessary but not sufficient condition for the generation of new knowledge. The distinctions between tacit and codified

knowledge, as well as between knowledge internal to the firm and knowledge external to it play a major role as much as the new understanding upon the implications of knowledge indivisibility and knowledge appropriability. A major distinction has to be made between learning and knowledge. The generation of new knowledge is the result of an intentional conduct induced by a specific process that can be successfully implemented only when a number of key conditions apply.

The definition of the inducement mechanism that obliges firms to actually generate new knowledge has been already much debated. This is the first major point of departure from the notion of knowledge as the automatic and spontaneous outcome of learning, put forward by Edith Penrose. Firms are reluctant to change their routines, their production processes, the networks of suppliers and their marketing activities as much as their goals and their understanding of the product and factor markets. Firms can overcome their intrinsic inertia and resistance to change only when a powerful failure mechanism is at work. Firms are pushed to take advantage of the tacit knowledge acquired by means of learning processes by emerging mismatches between their own beliefs, based upon perceptions, and related plans and the actual conditions of the markets for products and production factors[2]. Only when such a mismatch takes place and the quasi-irreversibility of decisions implemented impedes simple adjustments, firms are pushed, by emerging losses and performances below expected levels to react creatively by means of the introduction of innovations. To do so, the intentional and explicit generation of new technological and organizational knowledge becomes necessary (Antonelli, 1999, 2001, 2003; Ruttan, 1997, 2001).

Recent advances in cognitive economics confirm the role of intentional creativity in the generation of new knowledge and the specific behavioral context into which discoveries take place (Rizzello, 2003). As Nooteboom (2003: 225) properly articulates " discovery is guided by motive, opportunity and means. One needs an accumulation of unsatisfactory performance to generate motive; to overcome one's own inertia or that of others in organization. In markets, one also needs an

[2] See North (1997:226) "Competition forces organizations continually to invest in new skills and knowledge to survive. The kind of skills and knowledge individuals and their organizations acquire will shape evolving perceptions about opportunities and, hence, choices that will incrementally alter institutions….While idle curiosity is an innate source of acquiring knowledge among human beings, the rate of accumulating knowledge is clearly tied to the payoffs. Secure monopolies, be they organizations in the polity or in the economy, simply do not have to improve to survive. But firms, political parties, or even institutions of higher learning, faced with rival organizations, must strive to improve their efficiency. When competition is muted (for whatever reasons), organizations will have less incentives to invest in new knowledge and, in consequence, will not induce rapid institutional change."

opportunity of demand and/or technology. And one needs insights into what source and how to incorporate them in present competence"[3].

The transformation of the competence based upon learning processes into new, actual technological knowledge requires specific and dedicated efforts. The generation of new technological knowledge can be considered the specific activity of the firm and its distinctive function within the economic system: the firm is indeed the locus of technological discovery. Yet discovery and creativity are not an automatic, incremental, past dependent and hence deterministic activity guided by the sheer accumulation of competence based upon tacit learning, but rather the result of a complex path dependent process where at each point in time firms make explicit and intentional efforts to generate new technological knowledge. Such efforts are most likely to be successful when a number of contextual conditions apply.

The appreciation of the intentional, contextual and resource consuming activity necessary to actually generate new technological knowledge leads to dig deeper into the analysis of the direction or characteristics of the new knowledge being induced and hence generated by firms. Learning firms need to be able to select the direction of their innovation activities. Although learning localizes the cognitive base in a limited spectrum, or ray, from the original focal point of activity, there are still many possible directions along which the generation of new technological knowledge can be aligned. A variety of possible discoveries can be the outcome of the intentional valorization learning processes and the consequent accumulation of tacit knowledge. New technological knowledge do impinge upon the basic ground provided by learning by doing the current products, learning by using the current technologies and capital goods, learning by interacting with the actual variety of suppliers, competitors and customers. Yet the tacit knowledge and the competence acquired can be implemented and valorized in a variety of possible directions. The choice among an actual array of possible discoveries becomes a crucial issue. The intentional choice of the direction of the possible discoveries marks the second strong departure from the deterministic notion of the firm as an agent moving along a predefined

[3] See Greve (1998) who examines how performance feedback affects the probability of risky organizational. His empirical analysis in the radio broadcasting industry shows the consequences of shortfalls of performances on the probability of strategic change and their strong sensitivity to social and historical aspiration levels. Ocasio (1998) provides a theoretical reconciliation of theories of failure-induced change and threat-rigidity. The theory explicitly links the cognitive psychology that underlies risk-seeking behavior and threat-rigidity with the social groupings and cultural rules that structure thinking and decision making in organizations.

trajectory based upon past learning. As a matter of fact at each point in time the firm has in front a variety of possible directions towards which the creative activities can be ordered. Each needs to be assessed and the relative profitability needs to be valued both from the viewpoint of the costs of introduction and the revenue stemming from its introduction. Two basic elements can be considered specifically: external knowledge and idiosyncratic production factors as focusing incentives.

The key role of knowledge indivisibility provides the first contribution. As it is well known knowledge is characterized by substantial indivisibility; at the same time no firm can claim the command of the knowledge available. Knowledge external to the firm, at each point in time, is as necessary and relevant to knowledge internal to the firm, in order to generate new knowledge. The access conditions to external knowledge are a key conditional factor in assessing the chances of generation of new knowledge. The generation of new knowledge is the specific outcome of an intentional conduct and requires four distinct and specific activities: internal learning, formal research and development activities, and the acquisition of external tacit and codified knowledge. Each of them is indispensable. Firms that have no access to external knowledge and cannot take advantage of essential complementary knowledge inputs can generate very little, if no new knowledge at all, even if internal learning provides major contributions.

In the localized technological knowledge framework of analysis, in order to generate new knowledge, firms need to combine internal sources of knowledge such as intramuros research and development activities and learning processes with the systematic use of external knowledge as a primary input for the general production of new knowledge. No firm, in fact, can innovate in isolation. External knowledge is an essential input into the generation of new knowledge. External knowledge can be substituted to internal sources of knowledge only to a limited extent: full-fledged substitutability between internal and external knowledge cannot apply. Unconstrained complementarity however also appears inappropriate. Building on the large empirical evidence about the role of external knowledge, the hypothesis of a constrained multiplicative relationship can be articulated. External and internal knowledge, both in their tacit and codified form, are complementary inputs where none is disposable. The ratio of internal to external knowledge however seems relevant. Neither can firms generate new knowledge relying only on external or internal knowledge as input. With an appropriate ratio of internal to external knowledge instead internal knowledge and external knowledge inputs enter into a constrained multiplicative production

function. Both below and above the threshold of the appropriate combination of the complementary inputs the firm cannot achieve the maximum output.

The appreciation of the idiosyncratic character of much resources and its productive and competitive effects provides the second basket of analytical opportunities. The productivity of new technological knowledge, when applied to the actual production process, and the appropriability of the economic value stemming from its use, are much influenced by the relative price of the production factors being used. Firms that are able to identify idiosyncratic production factors upon which they exert a specific control that enables low purchasing costs can direct the introduction of new technologies so as to increase their role in their production process, and make an intensive use, so as to extract much higher rents from their knowledge generation activities for much a longer period of time. The identification and valorization of idiosyncratic resources becomes a clear and strong focusing device along which firms can align their research activities. The generation of new technological knowledge can be directed towards the introduction of new technologies that make possible the intensive use of such idiosyncratic production factors so as to reduce production costs and create barriers to entry and to imitation which prevent the dissipation of the economic rents stemming from their introduction.

The appreciation of the role of knowledge indivisibility and hence of the role of external knowledge and idiosyncratic production factors becomes a powerful tool to understand the criteria by means of which firm select the direction of the generation of new technological knowledge. Let us analyze their role in detail.

3. THE ROLE OF EXTERNAL KNOWLEDGE

The access to external knowledge is clearly conditional to the successful generation of new knowledge for each agent. External knowledge can be accessed by means of a variety of tools, ranging from transactions in the markets for knowledge to an array of interaction modes with public research centers, customers, suppliers and competitors. External knowledge is only potentially useful: systematic efforts have to be done in order to take advantage of such possibilities. To do so, firms rely on knowledge exploration strategies to identify the sources of knowledge, to assess whether and how to rely upon external or internal knowledge in the production of new knowledge one. Knowledge procurement is as relevant as knowledge production in the generation of new knowledge. A

corporation that is able to fully coordinate and centralize all the relevant learning and research activities and to combine them with the relevant sources of external knowledge, both tacit and codified, can successfully generate new knowledge. The purchase of patents and licenses in knowledge markets by means of knowledge transactions is by no means the single source of external knowledge. External knowledge can be accessed also by means of a variety of other tools, including the hiring of qualified personnel embodying the competence acquired by means of learning in other companies and an array of interaction modes with public research centers, customers, suppliers and competitors.

TABLE 1: MODES OF PRODUCTION OF NEW LOCALIZED KNOWLEDGE

	TACIT KNOWLEDGE	CODIFIED KNOWLEDGE
INTERNAL KNOWLEDGE	LEARNING	RESEARCH & DEVELOPMENT
EXTERNAL KNOWLEDGE	NETWORKING INTERACTIONS WITH CUSTOMERS, RIVALS, ACADEMICS AND SUPPLIERS; HIRING OF QUALIFIED PERSONNEL	KNOWLEDGE TRANSACTIONS WITH KIBS AND UNIVERSITIES; PURCHASE OF PATENTS AND LICENCIES IN THE MARKETS FOR KNOWLEDGE; MERGERS & ACQUISITIONS OF HIGH TECH START-UPS

The governance approach elaborated by Ronald Coase and Oliver Williamson can be successfully applied to the analysis of the relevant factors in knowledge generation. The characteristics of knowledge and

the details of its generation and dissemination process can be appreciated from the view point of the economics of governance especially when the basic ingredients of the resource based theory of the firm are taken into account and properly integrated into a single interpretative frame (Coase, 1937; Williamson, 1975, 1985, 1996; Penrose, 1959).

The integration of the transaction costs approach with the resource based theory of the firm shows that firms select their boundaries by means of the inclusion and exclusion of specific activities, including knowledge generation, exploitation and exploration ones, according to the characteristics of technological knowledge and to the related levels of knowledge transaction costs. Following the resource-based theory of the firm, the corporation is a resource pool designed and managed so as to implement the opportunities for the accumulation of both new technological and organizational knowledge. The rates of technological and organizational learning influence each other in shaping the dynamics of the firm and the evolving composition of the collection of activities that are retained within its boundaries and ultimately its growth (Teece, 2000; Antonelli, 2004).

Knowledge transactions and interactions costs can be identified and defined in terms of the costs of all the activities that are necessary to exchange bits of knowledge among independent parties. Two important distinctions must be introduced here. The first is between knowledge transaction costs on the demand side and knowledge transaction costs on the supply side (Antonelli, 2001 and 2003).

Knowledge transaction costs on the supply side define all the costs that agents bear to use the markets for knowledge as a product per se. Knowledge transaction costs on the supply side consist primarily of all the activities that are necessary to make sure that, while attempting to exploit proprietary knowledge, it does not leak out depriving the legitimate holder of part of, if not the whole revenue. Knowledge transaction costs on the supply side can also be quantified by the sum of the costs of the activities that are carried on to prevent disclosure and to secure the possession of proprietary knowledge plus the missing portions of revenue stemming from unintentional disclosure and the following leakage. Next to the problems determined by imperfect appropriability, the costs of using the markets for knowledge include more traditional activities such as marketing, advertising, technical assistance and in general al the activities that are necessary to identify perspective customers and to strike appropriate contract with them. The provision of technical assistance to the users of the technological knowledge is at the

same time a cause of considerable costs and an effective mechanism to prevent uncontrolled leakage and the opportunistic behavior of users. Technical assistance is the base on which to implement pricing strategies that take into account the effective amount of economic benefits stemming from the downstream use of the knowledge.

Knowledge transaction costs on the demand side define all the costs associated with the exploration activities in the markets for disembodied knowledge such as search, screening, processing, and contracting. Knowledge exploration strategies take into account knowledge transaction costs on the demand side in the context of the choice between 'make' internal knowledge or 'buy' external one. As it is well known the assessment of the actual quality of the knowledge can be difficult when the vendor bears the risks of opportunistic behavior and dangerous disclosure. A close interaction takes place between knowledge transaction costs on the demand side and knowledge transaction costs on the supply side.

When efficient markets for knowledge are available, the selection of knowledge activities that firms retain within their boundaries is much stronger. The scrutiny for the inclusion of knowledge generating activities and of their eventual valorization is in fact much more selective. The exploration for external sources of knowledge and knowledge outsourcing becomes common practice. Firms can rely on external providers for specific bits of complementary knowledge. Knowledge outsourcing on the demand side matches the supply of specialized knowledge intensive business service firms. Universities and other public research centers can complement their top-down research activities finalized to the production of scientific knowledge with the provision of elements of technological knowledge to business firms.

The second distinction is between static knowledge transaction costs and dynamic knowledge transaction costs. Static transaction costs are defined by the costs of using the markets to trade knowledge at each point in time and with no understanding of the stream of long term consequences engendered by the use of the markets. Dynamic transaction costs are defined in terms of opportunity costs of the governance of the stock of knowledge with respect to the stream of generation of new knowledge. Inclusion now yields the opportunity to appropriate the eventual benefits stemming from the accumulation of knowledge in terms of higher opportunities for the introduction of additional units of knowledge.

Coordination costs limit the valorization of internal learning and the number of complementary activities that can be internalized by each firm and hence the amount of knowledge that can be generated, implemented and exploited internally. Unit coordination costs also are sensitive to the variety of activities that need to be internalized. The larger is the rate of increase, with respect to the number of activities, of unit coordination costs and the larger is the number of complementary activities that cannot be retained within the boundaries of the firm. Because of internal coordination costs, important opportunities to exploit internal tacit knowledge and to generate new knowledge are missed. Large corporations are unable to implement all the opportunities they contribute to create (Arrow, 1974).

The application of transaction cost analysis to understanding the governance of localized knowledge requires the integration of the important notion of knowledge interaction costs. Knowledge does not spill freely and automatically in the atmosphere: dedicated efforts are necessary to create the institutional context into which external knowledge can be acquired and to reduce its uncontrolled leakage. The capability of agents both to retain some proprietary control and to communicate and hence to access external technological knowledge depends on the fabric of institutional relations and shared codes of understanding which help to reducing information asymmetries, the scope for opportunistic behavior and to building a context into which reciprocity, constructed trust and generative relationship can be implemented (Cohen and Levinthal, 1990).

Knowledge communication is necessary when knowledge is dispersed and fragmented, retained by a myriad of heterogeneous agents, and yet characterized by high levels of indivisibility with important potential benefits in terms of externalities stemming from its integration and recombination. Yet knowledge communication is not automatic. On the opposite, it is the result of much intentional activity designed to create a context conducive to combine variety and complementarity. Systematic networking is necessary to establish knowledge communication flows. The network structure of the system plays a key role in shaping the flows of knowledge communication and hence the availability of external knowledge. Specific, dedicated networking activities are necessary in order to manage the flows of knowledge that are not internal to each firm and yet cannot be reduced to arm's length transactions. Networking activities make knowledge interactions, as distinct from knowledge transactions, possible. Networking activities are a well specific –

indispensable- ingredient of the basic governance of knowledge (Freeman, 1991).

Firms often rely on networking interactions with other independent parties, to increase the proprietary control of their knowledge, to acquire external knowledge and to better exploit it. External knowledge can be acquired by taking advantage of the spillovers from the academic activities, and from localization in the proximity of other firms. Qualified user-producers interactions, both upstream, with suppliers, and downstream, with customers, are the source of new knowledge. Imitation of competitors also provides access to external knowledge, as well as qualified interactions with the scientific community. Knowledge dissemination is better controlled within networks of interactions based upon constructed and repeated interactions, qualified by contractual relations. The array of networking tools is ever increasing and includes both formal and informal mechanisms. Joint ventures, dedicated research clubs, sponsored spin-offs, patent-thicketing, technological platforms, cross-licensing, and in-house outsourcing are the main types of formal cooperative tools. Co-localization within technological districts and membership into epistemic communities are typical forms of networking procedures.

In sum, the firm exposed to a mismatch between her beliefs and related plans, and the eventual factor and market conditions is pushed to generate new knowledge and introduce new technologies. Such an intentional result requires dedicated activities: the valorisation of internal learning, the conduct of formal research and development activities, and the acquisition of external knowledge, both tacit and codified. Such activities entail the assessment of specific costs such as the costs of the coordination of the valorisation of internal learning, the knowledge transaction costs necessary to purchase codified knowledge in the markets for knowledge and the networking costs, necessary to implement the acquisition of external knowledge, both codified and tacit. Even tacit external knowledge does not spill freely in the air: its acquisition is itself the result of intentional activities. The generation of technological knowledge is clearly a path dependent process where internal cumulability based upon learning processes provides the past dependent component and the feedbacks of the external environment in the form of knowledge transaction and knowledge networking costs, as determined by the structure of communication flows and the quality of the social capital in place, act as the diverting forces, able to change the original path.

4. THE IDIOSYNCRATIC DIRECTION OF TECHNOLOGICAL KNOWLEDGE

The analysis of the generation of technological knowledge, as the intentional result of the conduct of firms makes it possible to highlight the choices of the firms engaged in competition. Each firm learns and builds up new capabilities and eventually discovers new possible applications for intangible production factors and competences that are found within its own boundaries. Such internal resources and intangible production factors are highly idiosyncratic as they are the result of a specific learning process and are difficult to replicate for other agents which do not share the very same historic process of growth.

Technological knowledge generated by firms has a strong idiosyncratic and path dependent character for two strong reasons. On the supply side we see that:

A) the generation of new technological knowledge relies on internal localized learning processes. Here localized learning makes reference to learning within the boundaries of the firm. According to Edith Penrose, in fact, innovative firms are successful when they try and make the most effective use of production factors that are not only locally abundant, but also internally -within its own boundaries- abundant. Such internal resources and production factors are highly idiosyncratic as they are the result of a specific learning process and are difficult to replicate for other agents which do not share the very same historic process of growth.

B) the search for new, more effective, uses of locally abundant production factors is a powerful alignment mechanism for the research strategies of a variety of learning agents that are co-localized and have access to the same pools of collective knowledge. Here the notion of localization acquires a strong geographic and institutional character. Each learning agent becomes aware of the collective endeavor directed towards the local search and in turn aligns its own research efforts in directions that can take advantage of the limited appropriability of the knowledge generated nearby as well as of the pervasive dynamics of knowledge cumulability and knowledge complementarity. Global research strategies require substantial efforts to build communication channels at distance, to explore relations with remote agents, localized in different institutional contexts and different knowledge pools. Agents localized in different factor markets moreover are likely to have built competence and to rely upon tacit knowledge based upon processes of learning by using different

techniques and different production factors. Global strategies may be effective only when the supply of local collective knowledge is diminished and knowledge communication and governance costs reduce its accessibility. In sum, firms have a clear incentive to generate idiosyncratic, rather generic knowledge, from a supply side.

As it is well known, the production that makes the most intensive use of locally abundant and hence cheaper production factors is most efficient, and it engenders systematic cost asymmetries when competitors have not access to the same factor markets. Hence firms have a strong incentive to generate a kind of technological knowledge such that it can direct the introduction of technological innovations towards technologies that rely more intensively on the production factors that are not easily accessible to competitors.

The analysis of market dynamics provides the basic elements to fully understand the mechanism at work, from the demand side. Since 'The theory of economic development' by Joseph Schumpeter it is well known that innovators can take advantage of a monopoly power that is, however, necessarily transient. Extra profits associated with the introduction of successful innovations stimulate the imitative entry of newcomers. Increased competition drives price-cost margins to minimum levels. Industrial dynamics however is more and more characterized by monopolistic competition cum barriers to entry among firms that are heterogeneous both with respect to their local factor markets and to their own competence and skills, organized by means of internal factor markets.

In such a market place the competitive advantage of innovators is based much more on the idiosyncratic mix of production factors that have contributed to shape the direction of technological change, than on the exclusive command of proprietary technological knowledge. Even if new competitors can imitate the new idiosyncratic and localized technology, their production process will be less effective than that of innovators because of the differences in the costs of production factors. In this context, the more specific is the technology introduced by innovators, i.e. the more it reflects the access conditions to idiosyncratic production factors for innovators, and the less likely is the possibility that newcomers, even when and if they succeed in grasping the new technological knowledge and imitate the new technology, will be able to match the production costs of innovators and hence reduce their competitive advantage.

Innovators relying on idiosyncratic production factors can command a cost advantage upon which long lasting barriers to entry and to mobility can be built. Each innovator becomes the local monopolist in a well-defined market niche. The size of the niche depends upon the specification of the products with respect to the preferences of consumers and upon the cross price elasticity with respect to other similar products. The latter in turn are built around the idiosyncratic competences of other competitors. Innovators will fix strategic prices in the niche according to the ease of mobility and entry of the competitors in the broader basket of niches competing for the demand of similar customers and the levels of cross price elasticity, that is the mobility of customers across the different niches[4].

4.1. A SIMPLE ANALYTICAL EXPOSITION.

The combination of these three mechanisms engenders a strong focusing incentive that direct strategically towards the selection of the direction of technological change. A simple formal exposition helps to clarify this point.

Let us assume that each firm has a budget available to fund research activities[5]. Such research activities can be directed towards the introduction of either new generic technologies that make it possible a symmetric shift of all the map of isoquants, or towards the introduction of localized technologies that affect only a limited portion of each isoquant, typically in the region where each firm is localized. Hence we have the following:

(1)TRD = GRD + LRD

Here TRD is the total budget available for research activities, GRD are the research activities that make it possible the introduction of generic technological change and LRD are the research activities that impinge upon learning processes and make it possible the introduction of localized technological changes. Hence:

(2) GT = a (GRD), where GT are new generic technologies.
(3) LT = b (LRD), where LT are new localized technologies.

[4] See Antonelli (2003. chapter 8) for the model.
[5] See chapter XI for the full specification of the inducement mechanism

We shall assume that, because of the effects of learning by doing, learning by using and learning by interacting with co-localized firms, a'>b'.

The new technologies have a direct effect on the output of the firm. We see respectively two extreme cases:

(4) $Y_g = c\ (K, L, GT)$
(5) $Y_l = d\ (K, L, LT)$

In the first case the firm uses only the generic technology, in the second the firm uses only the localized technology. The generic technology has lead to a neutral technological change with no modifications in the output elasticity of the production factor K and L. The localized technology has lead to the introduction of a new technology that makes a more intensive use of the locally abundant production factors. When factors are not equally abundant in each local factor market, it is clear that $Y_l > Y_g$.

Equations (4) and (5) can be combined into the traditional frontier pf possible production:

(6) $Y_g = e\ (Y_l)$

The solution to the optimization problem is easily found with an isorevenue that defines the possible revenues that can be earned with the alternative production functions considered. The slope of the isorevenue measures the ratio of the prices of the products manufactured with a new generic technology P_g to the prices of the products manufactured with a new localized technology P_l . According to the analysis there are good reasons to believe that $P_l > P_g$. The products manufactured with a localized technology, make a more intensive use of the locally abundant factors, including those internal to the firm, hence enjoy systematic cost asymmetries with respect to imitators and hence can take advantage of substantial barriers to entry and to mobility. In these circumstances their mark-ups are likely to last longer.

The equilibrium is found where:

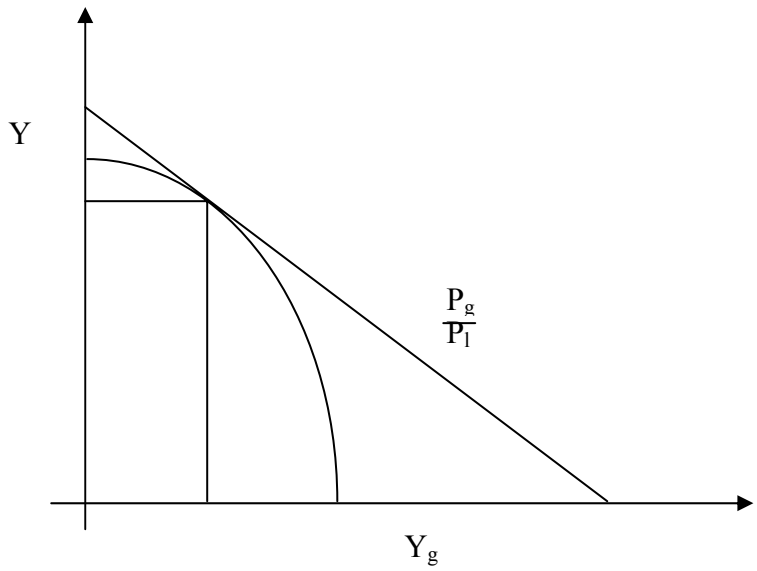
(7) $d\ Y_g / d\ Y_l = P_l / P_g$

Clearly there are strong incentives to select the mix of more biased technologies, than generic ones.

A simple geometric exposition can help to grasp the point. As it is shown in Diagram 1, the shape of frontier of production possibilities which considers the trade-off between the levels of output Y_l which can be attained with the introduction of a new technology that makes intensive use of locally abundant and idiosyncratic production factors and the levels of output Y_g that can be attained with the introduction of a new technology which use generic production factors, is clearly asymmetric. Moreover the slope of the isorevenue, much smaller than 1, reflects the positive effects for innovators of the cost asymmetry with respect to imitators, which have not access to the same idiosyncratic production factors.

Optimization clearly favors the introduction of a mix of technologies based upon the intensive use of locally abundant and idiosyncratic production factors.

DIAGRAM 1. OUTPUT AND REVENUE MAXIMIZING INCENTIVES TO MAKE INTENSIVE USE OF IDIOSYNCRATIC INNOVATIONS



In such conditions it is clear that firms induced to introduce new technologies by unexpected mismatches between plans and actual market conditions, will define a budget of resource to face in a creative way the new market context. Such a budget of resources for innovation activities will be invested in a local search that will generate additional localized and hence idiosyncratic technological knowledge able to make the most

intensive use of locally abundant factors and to take advantage of the positive effects of the local pools of collective knowledge. Such localized technological knowledge will make it possible to introduce technological innovations that make the most systematic use of idiosyncratic production factors both because output levels are higher, for given levels of inputs, and because the relative price of products which make intensive use of idiosyncratic production factors reflect the positive effects, for innovators, of higher barriers to entry and to mobility for perspective imitators and hence monopolistic market power which is lasting for a longer stretch of time.

In sum, the generation of technological knowledge and the eventual technological change is localized by: a) the local search for access to existing pools of external knowledge and hence the participation in commons of collective knowledge where interactions and transactions are shaped by proximity; b) the costs-reducing use of most effective locally idiosyncratic production factors; c) the output-increasing strategy of agents that try and reduce the effects of competitive imitation and imitative entry by means of the use of idiosyncratic production factors and the related cost asymmetries for heterogeneous agents.

5. CONCLUSIONS

The integration of the resource based theory of the firm with the tradition of analysis based upon the notion of localized technological change and the transaction costs approach yields important dynamic results when the analysis focuses the generation of new technological and organizational knowledge.

The generation of new knowledge is not the automatic and spontaneous product of internal learning processes. Internal learning is a necessary, but not sufficient condition for the generation of new knowledge. Intentional, explicit and selective strategies are necessary in order to generate new knowledge. Moreover, because of intrinsic knowledge indivisibility and its twin character of both an input and an output, the acquisition of technological knowledge external to each firm is a necessary and indispensable activity in the generation of new knowledge for each firm.

Technological knowledge generated firms has a strong idiosyncratic character that is influenced by the internal learning processes, as well as

by the local structure of knowledge interactions and the characteristics of local factor and product markets.

At each point in time the generation of new knowledge by each firm is influenced by the structure of local interactions that shape the access to the knowledge generated within the system. Each firm, however, is able to interact with the system. This takes place at two levels: A) by changing the amount of knowledge made available to the other firms; B) by changing the structural conditions of the systems in terms of topology of communication channels and access conditions.

6. REFERENCES

Antonelli, C. (2004), The economics of governance: The role of localized technological change in the interdependence among transaction, coordination and production, in Green, K., Miozzo, M. and Dewick, P. (eds.), *Knowledge and Technology: Implications for Firm Strategy and Industrial Change*, Cheltenham, Edward Elgar, 2004.

Arora, A. and A. Gambardella (1994), The changing technology of technical change: General and abstract knowledge and the division of innovative labour, *Research Policy* 23, 523-532.

Arora, A., Fosfuri, A. and Gambardella, A. (2001), *Markets for technology*, Cambridge, MIT Press.

Argyres, N.S. (1995), Technology strategy governance structure and interdivisional coordination, *Journal of Economic Behavior and Organization* 28, 337-358.

Arrow, K. J. (1962b), The economic implications of learning by doing, *Review of Economic Studies* 29, 155-173.

Arrow, K. J. (1969), Classificatory notes on the production and transmission of technical knowledge*, American Economic Review* 59, 29-35.

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

Brusoni, S., Prencipe, A., Pavitt, K. (2002), Knowledge specialisation and the boundaries of the firm: Why do firms know more than they do?, *Administrative Science Quarterly* 46, 597-621.

Carroll, G.R. and Teece, D.J. (1999), *Firms markets and hierachies. The transaction cost economics prospective*, Oxford, Oxford University Press.

Casson, M. (1997*), Information and organization: A new perspective on the theory of the firm*, Oxford, Oxford University Press.

Cohen, W.M. and Levinthal, D.A. (1989), Innovation and learning: The two faces of R&D*, Economic Journal* 99, 569-596.

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

Cooper, D.P. (2001), Innovation and reciprocal externalities: Information transmission via job mobility, *Journal of Economic Behavior and Organization* 45, 403-425.

David, P.A. (1997), *Path dependence and the quest for historical economics: One more chorus of the ballad of QWERTY*, University of Oxford Discussion Papers in Economic and Social History, Number 20.

David, P.A. (2000a), Path dependent learning, and the evolution of beliefs and behaviours, in Pagano, U. and Nicita, A. (eds), *The evolution of economic diversity*, London, Routledge.

David, P.A. (2000b), Path dependence and varieties of learning in the evolution of technological practice, Ch. 10 in Ziman, J. (ed), *Technological innovation as an evolutionary process*, Cambridge University Press, Cambridge.

David, P.A. (2001), Path dependence, its critics, and the quest for 'historical economics', in Garrouste, P. and Ioannidis, S. (eds), *Evolution*

and path dependence in economic ideas: Past and present, Edward Elgar, Cheltenham,.

Fai F. (2003), *Corporate technological competence and the evolution of technological diversification*, Cheltenham, UK: Edward Elgar.

Fai, F. and von Tunzelmann, N. (2001), Scale and scope in technology: Large firms 1930/1990*, Economics of Innovation and New Technology* 10, 255-288

Freeman, C. (1991), Networks of innovators: A synthesis of research issues, *Research Policy* 20, 499-514.

Fransman, M. (1994), Information, knowledge, vision and theories of the firm, *Industrial and Corporate Change* 3, 713-758.

Holmstrom, B. (1989), Agency costs and innovation, *Journal of Economic Behavior and Organization* 12, 305-327.

Holmström, B., Roberts, J. (1998), The boundaries of the firm revisited, *Journal of Economic Perspectives* 12 , 73-94.

Greve, H.R., (1998), Performance, aspirations, and risky organizational change, *Administrative Science Quarterly* 43, 58-86

Langlois, R.N. and Robertson, P. L. (1995), *Firms markets and economic change. A dynamic theory of business institutions*, London, Routledge.

Langlois, R.N. and Foss, N.J. (1999), Capabilities and governance: The rebirth of production in the theory of economic organization, *Kyklos* 52, 201-218.

Nooteboom, B. (2000), *Learning and innovation in organizations and economics*, Oxford, Oxford University Press.

Nooteboom, B. (2003), Managing exploration and exploitation, in Rizzello, S. (ed.), *Cognitive developments in economics*, Routledge, London.

North, D. C. (1997), Some fundamental puzzles in economic history, in Arthur, W.B., Durlauf, S.N. and Lane, D. (eds.) (1997), *The economy as an evolving complex system II*, Addison-Wesley, Redwood City, CA.

North, D. C. and Wallis, J. (1994), Integrating institutional change and technical change in economic history. A transaction cost approach, *Journal of Institutional and Theoretical Economics* 150, 609-624.

Ocasio, W. (1995), The enactment of economic adversity. A reconciliation of theories of failure-induced change and threat-rigidity, *Research in Organizational Behavior* 17, 287-331

Patrucco, P.P. (2003), Institutional variety, networking and knowledge exchange: Communication and innovation in the case of the Brianza technological district, *Regional Studies* 37, 159-172.

Patrucco, P.P. (2005), The emergence of technology systems: knowledge production and distribution in the case of the Emilian plastics district, *Cambridge Journal of Economics*, 29, 37-56

Pisano, G.P. (1990), The R&D boundaries of the firm: An empirical analysis, *Administrative Science Quarterly* 35, 153-76.

Rizzello, S. (ed.) (2003), *Cognitive developments in economics*, Routledge, London.

Ruttan, V.W. (1997), Induced innovation evolutionary theory and path dependence: Sources of technical change, *Economic Journal* 107, 1520-1529.

Ruttan, V.W. (2001), *Technology growth and development. An induced innovation perspective*, Oxford University Press, Oxford.

Teece, D.J. (1998), Capturing value from knowledge assets: The new economy, markets for know-how and intangible assets, *California Management Review* 40, 55-79.

Teece, D.J. (2000), *Managing intellectual capital*, Oxford, Oxford University Press.

Wang, Q. and Von Tunzelmann, G. N. (2000), Complexity and the functions of the firm: breadth and depth, *Research Policy* 29, 805-818.

Williamson, O.E. (1975), *Markets and hierarchies: Analysis and antitrust implications*, New York, Free Press.

Williamson, O. E. (1985), *The economic institutions of capitalism: Firms, markets, relational contracting,* New York, Free Press.

Williamson, O. E.(1996), *The mechanisms of governance*, New York, Oxford University Press.

Williamson, O. E. and Winter, S.G. (eds.) (1993), *The nature of the firm*, Oxford, Oxford University Press.