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## Localized appropriability: Percuniary externalities in knowledge exploitation

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# Working Paper Series

## Localized Appropriability: Pecuniary Externalities in Knowledge Exploitation

Cristiano Antonelli

Manchester Business School Working Paper No 542

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## **Abstract**

Pecuniary externalities are crucial in shaping the strategies to value the distinctive competences and the economic success of innovative firms. The analysis of conditions for localized knowledge appropriation and exploitation makes it possible to identify idiosyncratic production factors. The introduction of directed technological change biased towards intensive usage provides the opportunity for the exploitation of technological knowledge.

## **Keywords**

Pecuniary externalities; localized appropriability; direction of technological change

## **JEL Classification**

O31

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# **LOCALIZED APPROPRIABILITY: PECUNIARY EXTERNALITIES IN KNOWLEDGE EXPLOITATION<sup>1</sup>**

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**ABSTRACT.** Pecuniary externalities are crucial in shaping the strategies to value the distinctive competences and the economic success of innovative firms. The analysis of conditions for localized knowledge appropriation and exploitation makes it possible to identify idiosyncratic production factors. The introduction of directed technological change biased towards intensive usage provides the opportunity for the exploitation of technological knowledge.

**KEY WORDS:** PECUNIARY EXTERNALITIES; LOCALIZED APPROPRIABILITY; DIRECTION OF TECHNOLOGICAL CHANGE.

**JEL CLASSIFICATION:** O31

## **1. INTRODUCTION**

Recent advances in the economics of knowledge enable important progress to be made in understanding the key role of pecuniary externalities in knowledge exploitation. The analysis of the characteristics of localized knowledge appropriability embodied in idiosyncratic production factors plays a key role in shaping a firm's intentional strategy

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regarding the direction of technology. The firm is viewed as a learning agent capable of creative reactions induced by market forces. Building upon learning processes, each firm elaborates and intentionally implements strategies of both knowledge generation and exploitation. These strategies include exploring factor markets and identifying the idiosyncratic production factors that are convenient to use intensively.

In such a context the notion of pecuniary externalities is relevant. Pecuniary externalities apply when the prices of production factors differ from equilibrium levels and reflect the effects of external forces. According to Scitovsky (1954) pecuniary external economies consist of indirect ‘interdependence among producers through the market mechanism’ (p.146).<sup>2</sup> There are pecuniary externalities when the market price of a production factor, for each specific quantity, is below its marginal productivity in equilibrium. Pecuniary externalities differ sharply from ‘technological’ externalities. Technological externalities are found when there is direct interdependence among firms and unpaid inputs generated by each firm enter the production function of every other firm (Antonelli, 2007).

Pecuniary externalities stem from the effects of the dynamics of growth. The growth in demand and the increase in the division of labor with consequent entry of new firms in upstream and lateral industries in specific geographical and regional clusters have the ultimate effect of lowering the market price for the products that are an input of the production process in downstream industries (Kaldor, 1981).

The analysis of localized appropriability articulates the integration of the theory of the firm developed by Edith Penrose with the notion of localized technological change originally described by Joseph Stiglitz, Anthony Atkinson (1969), and then by Paul David (1975) in the context of the theory of production and the economics of innovation and technological change in their analysis of the contexts into which the firms implement their innovative strategies. An appreciation of the localized context, qualified in terms of pecuniary externalities, into which technological knowledge can be appropriated better and the direction of the technological change is chosen so as to increase its exploitation, provides important clues to understand the dynamics of technological

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<sup>2</sup> As Scitovsky notes: “This latter type of interdependence may be called pecuniary external economies to distinguish it from technological external economies of direct interdependence” (p.146)

change and its implication for the implementation of a firm's innovative strategies.

The rest of the paper is structured as follows. Section 2 elaborates the notion of localized appropriability and highlights the role of pecuniary externalities. Section 3 develops the analysis in terms of the profitability of introducing technological knowledge which makes the intensive use of idiosyncratic production factors possible both in terms of reducing production costs and increasing in the appropriability of the rents stemming from the generation of new technological knowledge. Section 4 elaborates the dynamic implications of the analysis in terms of innovation cascades. The conclusions summarize the main results and explore the implications for strategic decision-making.

## **2. KNOWLEDGE APPROPRIABILITY AND PECUNIARY EXTERNALITIES**

The path breaking contributions of Richard Nelson (1959) and Kenneth Arrow (1962a) who first analyzed knowledge as an economic good per se, have shaped the early economics of knowledge. This strand of analysis lead to the identification of a number of key characteristics of technological knowledge such as non-divisibility, non-appropriability, non-rivalry in use, non-excludability. The economic analysis of knowledge, as an economic good, makes it clear that actually knowledge is a public good. Intellectual property right regimes provide a remedy to intrinsic non-appropriability.

The analysis of knowledge as a public good based upon its non-appropriability can be contrasted with the notion of embodied appropriability. In the Schumpeterian approach knowledge can be appropriated when innovators are large corporations that enjoy the advantages of barriers to entry based upon increasing returns to scale (Schumpeter, 1942). Existing barriers to entry become barriers to imitation for new products. Lead times provide innovating incumbents with the opportunity to reap the advantages of economies of scale and scope before potential competitors are able to imitate the innovation. The corporation is the institution that provides innovators with the opportunity and the incentives to appropriate and exploit technological knowledge (Chandler, 1962, 1977, 1990)

David Teece has enriched the Schumpeterian analysis of embodied appropriation. Firms can try and exploit their technological knowledge by bundling it with complementary assets that are under their exclusive

control (Teece, 1998 and 2000). In this approach firms test and search for complementary assets according to the characteristics of their proprietary knowledge.

The Schumpeterian legacy can be further implemented with the notion of localized appropriability. Localized appropriability, is the possibility for inventors to appropriate the stream of benefits stemming from the introduction of innovations, as a result of the downstream vertical integration of knowledge, purposely generated, in products and production processes that are highly idiosyncratic and as such enable long-lasting costs advantage to be manufactured. In such a approach firms try and direct the generation of technological change according to the characteristics of the idiosyncratic inputs that have been identified. In order to achieve localized appropriability firms need to elaborate a clear technological strategy. This approach reverses Teece's argument. According to which firms search for complementary assets, once they have a piece of technological knowledge they want to exploit. In our approach instead, the identification of idiosyncratic production factors becomes the focusing mechanism that directs the generation of new technological knowledge and the introduction of technological innovations. This approach is the result of quite a long analytical process that should be considered with care (Antonelli, 1995, 1999).

In the Arrovian top-down approach, technological knowledge is mainly viewed as the result of a top-down process. Scientific knowledge is generated in universities in the form of general principals and universal laws. Eventually these findings may be applied to production processes so as to feed the generation of new technological knowledge. The Arrovian approach has been challenged by the bottom up approach according to which bottom-up processes of learning are the main, if not the exclusive source of knowledge. The resource-based theory of the firm has provided the foundations to this approach and has highlighted the key role of learning routines in the generation of knowledge. In such an approach to the economics of knowledge the distinction between tacit and codified knowledge plays a key role.

The resource-based theory of the firm presents learning as the joint product of current activities and hence assimilates knowledge to learning. Edith Penrose (1959) identifies the firm, its organization and its routines, as the privileged actor in the learning process. The firm precedes the production function as its primary activity consists in the generation of new technological knowledge. Each firm, as is well known, learns and builds up new capabilities and eventually discovers new possible applications for production factors and competences that are found within

its own boundaries. According to the resource-based theory, in other words, 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 abundant, i.e. within its own boundaries. (Foss, 1997 and 1998). The bottom-up approach to understanding the dynamics of knowledge stresses the role played by internal learning processes, as the necessary and sufficient condition for the generation of new knowledge at large (Foss and Mahnke, 2000).

The economics of localized technological change makes it possible to implement the resource-based theory of the firm and hence contribute a bottom up approach to the economics of knowledge in three cardinal points: a) the qualification of the conditions for generation as shaped by the localization of the learning process; b) the emphasis upon the intentional decision making that stems from the creative reaction of innovative firm; c) the notion of localized appropriability. Let us analyze then in turn.

## **2.1 LOCALIZED LEARNING**

The analysis of learning has been much qualified and sharpened by the insight of Anthony Atkinson and Joseph Stiglitz (1969) who introduced the robust hypothesis that technological change can take place only in a limited technical space, defined in terms of factor intensity. Technological change is localized because it has limited externalities and affects only a limited span of the techniques, contained by a given isoquant, that are identified by the actual context of learning, in the proximity of equilibrium conditions where the firms have been producing. In other words technological change can only take place where firms have been able to learn: the localization here is strictly defined in terms of factor intensity and with respect to the techniques in place at each point in time.

The localized approach paves the way to implementing a broader understanding of the determinants and conditions that qualify the generation of technological knowledge. The notion of localized technological knowledge in fact makes it possible to highlight the role of knowledge as a joint-product of the economic and production activity. Agents learn how, when, where and what, also and mainly, from their experience, accumulated in daily routines. Firms, however, can also generate new technological knowledge by means of research and development activities: learning is not the single input into the generation of new knowledge.



The introduction of new technologies is constrained by the amount of competence and experience accumulated through learning processes in specific technical and contextual procedures. Agents, in this approach, can generate new knowledge, only in limited domains and fields where they have accumulated sufficient levels of competence and experience. A strong complementarity must be assumed between learning, as a knowledge input, and other knowledge inputs such as from R&D laboratories, within each firm (Antonelli, 2001).

Learning indeed is one of the basic sources of new technological knowledge. As such it exerts a strong and clear effect in terms of defining 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 impinging upon the specific form of learning that is actively implemented and the context in which it takes place (Antonelli, 1995, 1999, 2001).

## **2.2 CREATIVE REACTION AND DECISION MAKING**

In the analyses of both Penrose and Atkinson-Stiglitz, technological change is localized and constrained by organizational routines, but it is the automatic result of learning without any intentional and explicit effort. In the economics of localized technological change, instead, the introduction of innovations is the result of intentional decision-making.

Localized technological knowledge is the result of the intentional valorization of potential competences based upon learning. The generation of new knowledge is viewed to be the result of an intentional conduct induced by a specific process that can be successfully implemented only when a number of key conditions apply.

Knowledge is no longer regarded as the automatic by-product of learning, but rather the result of an intentional process and explicit decision-making. The role of Schumpeterian creative reaction, emphasized in the localized technological change approach, makes it possible to overcome this limitation (Schumpeter, 1947). The innovation process is activated when and if emerging out-of-equilibrium dynamics and mismatches between expected and actual conditions of both product and factor markets and performances induce firms to change their routines. Only

then, tacit knowledge, accumulated by means of learning processes, is actually converted into technological knowledge and new technologies are finally introduced (Antonelli, 1995 and 1999).

The appreciation of the role of intentional decision-making in the generation of new knowledge, and specifically the identification of the creative reaction that pushes firms to actually generate new knowledge, provides the second major point of departure from the notion of knowledge as automatic and spontaneous outcome of learning, put forward by Edith Penrose. Firms are reluctant to change their routines, their production processes, their 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<sup>3</sup>. Only when such a mismatch takes place and the quasi-irreversibility of decisions implemented impedes simple adjustments, are firms pushed, by emerging losses and performances below expected levels to react creatively and introduce innovations. In order to do this, the intentional and explicit generation of new technological and organizational knowledge becomes necessary.

The integration of the induced technological change approach into the Schumpeterian tradition makes it possible to see that out-of-equilibrium conditions both in factor and product markets induce firms to change not only their techniques but also their technologies with the introduction of innovations (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 in which discoveries take place (Rizzello, 2003). As Nooteboom (2003: 225) properly articulates “discovery is guided by motive,

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<sup>3</sup> 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 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 opportunity of demand and/or technology. And one needs insights into what source and how to incorporate them in present competence”<sup>4</sup>.

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 in fact the locus of technological discovery. Yet discovery and creativity are not automatic, incremental, past dependent, i.e. deterministic activities guided by the sheer accumulation of internal 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<sup>5</sup>. Such efforts are most likely to be successful when a number of contextual and external conditions apply.

### **2.3 LOCALIZED APPROPRIABILITY**

An appreciation of the intentional, contextual and resource consuming activity necessary to actually generate new technological knowledge leads to digging deeper into the analysis of the factors affecting the direction or characteristics of the new knowledge generated by firms. The conditions for knowledge appropriation and exploitation exert a powerful feedback pressure upon the generation of new technological knowledge.

Along these lines it seems now clearer and clearer that not only is the generation of knowledge the result of intentional activities that build upon internal learning processes which are still constrained by an array of external and localized complementary conditions. Knowledge exploitation, as well, is heavily constrained and shaped by the specific context of utilization. The localized conditions of knowledge usage affect its appropriability appreciably: the notion of localized appropriability has important consequences (March, 1991; Antonelli, 2003).

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<sup>4</sup> See Greve (1998) who examines how performance feedback affects the probability of risky organization. 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.

<sup>5</sup> Past dependence defines dynamic processes characterized by high levels of sensitivity of the initial conditions. Path dependence stresses the possibility of changing the direction of non-ergodic processes.

Learning firms need to select the direction of their innovation activities strategically. Although learning localizes the cognitive base in a limited spectrum of rays, 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 of learning processes and the consequent accumulation of tacit knowledge. New technological knowledge does impinge upon the basic ground provided by learning by making the current products, learning by using the current technologies and capital goods, learning by interacting with the current variety of suppliers, competitors and customers. The tacit knowledge and the competence acquired can be implemented and valued 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 appreciable departure from the deterministic notion of the firm as an agent moving along a predefined trajectory based upon past learning. As a matter of fact at each point in time the firm is faced by 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 application.

Here an important step forward can be made if the factors that constraint or stimulate the selection of the direction of the sequential steps and act as focusing mechanisms are identified and analyzed within a single framework. The characteristics of knowledge and idiosyncratic production factors provide important help in identifying the role of such focusing mechanisms.

The notion of pecuniary externalities plays a key role in this context.

With a given technology and assuming standard substitution among inputs, producers have a clear incentive to increase the intensity of utilization of production inputs characterized by pecuniary externality. Hence the input intensity of such factors will be higher in some specific locations than in others. In a dynamic context where technology is endogenous, innovators have a strong incentive to direct the introduction of new technologies so as to increase the intensity of production factors that are available at prices that are below their marginal productivity. In a dynamic context, consequently, the input intensity of the production

factors that happen to be characterized by pecuniary externalities will be much stronger than in a static context. Technological change works as a meta-substitution process.

Pecuniary externalities become a factor of specialization and, in a dynamic context, where technological change is endogenous, they are a factor that shapes the direction of technological change. Pecuniary externalities provide a novel and fruitful tool to understand the relationship between the generation of technological knowledge and its exploitation. So far it has found little application, as the literature has explored more systematically the consequences of knowledge non-appropriability in terms of 'direct interdependence' non-mediated by the market mechanism (Beaudry and Breschi. 2003; Malerba, 2005).

As a matter of fact the notion of pecuniary externalities provides the foundations on which to elaborate a new understanding of localized appropriability and hence a new view of the levels of incentives pushing for the generation of new technological knowledge. Such incentives are provided by the market place within the context of the resource based theory of the firm enriched by the economics of localized technological change.

The identification of the sources of pecuniary externalities consisting in local endowments of idiosyncratic production factors provides in fact the opportunity to substantially increase both the absolute effects of the technological change that a firm can generate and its appropriability. The intentional direction of technological changes towards the systematic exploitation of pecuniary externalities -stemming from the local endowments of idiosyncratic production factors- makes it possible to increase the gains in terms of efficiency for a given level of resources invested in the generation of new technological knowledge and new technologies and to appropriate them better.

The new understanding of the role of localized knowledge appropriability leads to a new appreciation of the idiosyncratic character of local resources and its productive and competitive effects and also provides a new basket of analytical opportunities to grasp the key role of the specific and localized conditions that affect the actual chances of firms to exploit the technological knowledge they can generate.

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. The identification of production factors that are idiosyncratic becomes a crucial issue. Production factors are idiosyncratic when firms can exert a specific control over them which provides low and exclusive acquisition costs. Firms which are able to identify idiosyncratic production factors can direct the introduction of new technologies in such a way that their role in their production process is increased, and they are used intensively and thus much higher rents are extracted 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 exploitation of such idiosyncratic production factors so as to reduce production costs and create barriers to entry and to imitation. Such barriers to entry and imitation based upon the intensive use of idiosyncratic production factors prevent the economic rents stemming from their introduction from being dissipated and hence increasing appropriability.

The appreciation of the role of localized knowledge appropriability and hence of biased technological change towards the intensive use of idiosyncratic production factors becomes a powerful tool to understand the criteria which firms use to select the direction of the generation of new technological knowledge. A full-fledged economic theory regarding the distinctive competence of the firm that includes the context, in which the firm is based, can be elaborated impinging upon these elements.

### **3. LOCALIZED KNOWLEDGE APPROPRIABILITY AND THE IDIOSYNCRATIC DIRECTION OF TECHNOLOGICAL KNOWLEDGE**

Following a well established traditional analysis of technological change at the system level (Kennedy, 1964; Samuelson, 1965; Ruttan, 1997; Acemoglou, 2002) it is well known that the intensive use of more abundant and hence cheaper production factors makes it possible to increase total factor productivity more effectively. Yet little attempt has been made, so far, to integrate this line of analysis, regarding the direction of technological change, with the theory of the firm and specifically with the analysis of technology strategy at the firm level.

The integration of these two levels of analysis makes it possible to grasp what role the conditions of usage of knowledge play as an incentive towards the selection of knowledge generation strategies at the firm and regional level. The direction of technological change has a robust effect on the results in terms of performance both at the level of the economic system and at the level of the firm. This is especially true in a globalized economy where firms, based in local, heterogeneous factor markets compete on global homogeneous product markets (Antonelli, 2006).

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 and factor markets. As is well known, production that makes the most intensive use of locally abundant and hence cheaper production factors is the most efficient, and it engenders systematic cost asymmetries when competitors have not access to the same factor markets.

Here the working of pecuniary externalities is clear. When the local endowments provide a supply of production factors at prices that are below the average level and cannot be easily accessed by other firms, the local incumbents have the opportunity to direct their innovations in such a way that barriers to entry are created. Rivals may be able to imitate the new products that embody the new knowledge, but cannot compete on the same cost levels because they have not access to the same pecuniary externalities. Pecuniary externalities become a source of barriers to entry based upon production costs. Barriers to entry, built upon pecuniary externalities, are a substitute for barriers to imitation.

An analysis of market dynamics provides the basic elements to fully understand the mechanism at work, from the demand side. Since the publication of 'The theory of economic development' by Joseph Schumpeter (1934) 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 increasingly 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 mix of idiosyncratic 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 the 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 use of idiosyncratic production factors that are specific to the innovators, the less likely it is possible 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 the pecuniary externalities provided by 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 is 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 to satisfy the demand of similar customers and the levels of cross price elasticity, that is to say the mobility of customers across the different niches.

Let us consider a firm which is able to generate a given amount of technological knowledge that is the result of the intentional valorization of its internal learning processes. The firm can direct such technological knowledge towards the introduction of idiosyncratic technological change which shapes the production function in such a way that the output elasticity of idiosyncratic production factors (I) is much higher than the output elasticity of generic production factors (G). This is convenient when, for the innovating firm, locally abundant production factors are available at a price ( $r$ ) which is lower than the price of the other production factors ( $p$ ): i.e. when  $r < p$ . Conversely, the introduction of generic technological change has no effect on the ratio of output elasticities. In other words the generation of (more) generic knowledge leads to the introduction of a (more) neutral technological change with no modifications in the output elasticity of the production factors G and I.



To make this point clear let us consider a standard production function prior to the introduction of the new technology:

$$(1) Y(t) = (I^E G^F),$$

where  $I$  and  $G$  are respectively the idiosyncratic and generic inputs;  $E$  and  $F$  measure their output elasticities.

After the introduction of respectively generic-intensive and idiosyncratic-intensive technological changes, the new alternative production functions can be specified as it follows:

$$(2) Y(t+1)_g = A (I^u G^v),$$

$$(3) Y(t+1)_l = A (I^s G^t),$$

$$(4) C = rI + pG,$$

where at time  $t+1$  after the introduction of the new technology,  $Y_l$  is the production process that uses an idiosyncratic-intensive technology and  $Y_g$  is the production process that uses a generic-intensive technology;  $u$ ,  $v$ ,  $s$ , and  $t$  measure the different output elasticities. Hence by comparing equation (1) and equation (2) we see that  $u < E$ ;  $s > E$ .

Let us now consider the effects of the alternative directions of technological knowledge in terms of knowledge exploitation. When factors are not equally abundant in each local factor market ( $r < p$ ), it is clear that the unit costs ( $CY_l$ ) of the goods manufactured by means of an intensive use of locally abundant and idiosyncratic factors are lower than the costs ( $CY_g$ ) of the goods manufactured with generic-intensive technologies that rely upon inputs that are available to every firm at the same price:

$$(5) CY_l < CY_g.$$

Generally it is clear that for any given inequality between the unit costs of generic and idiosyncratic inputs such that  $r < p$ , the productivity of a given amount of new technological knowledge will be larger, the larger is the bias in the new technology as measured by the ratio of  $s/t$ . For a given  $r < p$ , the larger  $s/t$  is the higher is the total factor productivity stemming from a given amount of technological knowledge.

Composition effects as defined by the relative abundance of inputs in local factor markets are major external factors in shaping the direction of technological change. When the most productive factor is cheaper and hence it is used more intensively, and the least productive factor is more expensive and hence it is used less intensively, production costs are

lowest. The growth of total factor productivity derived from the introduction of a given technology is higher; the higher is the output elasticity of the productive factor, which locally is most abundant.

Composition effects act as sorting devices. For a given supply of new and rival technologies, with similar shift effects, composition effects act as powerful selection devices and the rates of success in introducing new technologies will be influenced by the local conditions in the factor markets. Labor-intensive technologies will be far more successful in labor abundant countries and capital-intensive technologies will be adopted faster in capital abundant countries. The introduction of new technologies which are characterized by high levels of output elasticity of labor, but small shift effects, might be delayed forever in capital-intensive countries. This analysis is most important when the global economy is considered: in the global economy in fact firms based in highly heterogeneous local factor markets compete in quite homogeneous product markets. Different agents, rooted in different regions, with different endowments and hence different conditions in their local factor markets may react with similar levels of creativity to similar changes in their current conditions, introducing new technologies with marked differences in terms of factor intensity not only because of the effects of internal localized learning and the conditions of access to the local pools of collective knowledge, but also because of the selection mechanism stemming from powerful composition effects. Here composition effects, stemming from the pecuniary externalities associated to the costs of well identified and idiosyncratic inputs, act as a focusing mechanism that explains both the direction of the introduction of new technologies and their selective adoption and diffusion (Antonelli, 2003).

Finally, we consider the price at which the goods that have been manufactured with the new technologies can be sold. The products manufactured with a more idiosyncratic-intensive technology, which makes a more intensive use of the locally abundant factors, including those internal to the firm, and which are not available at the same conditions to competitors, enjoy systematic cost asymmetries with respect to imitations and hence these firms can take advantage of substantial barriers to entry and to mobility. In product markets characterized by monopolistic competition, incumbents protected by barriers to entry and to mobility can fix high prices for their products, far higher than those of competitors. This is not the case when technological change is generic-intensive: every firm can use production factors that are not idiosyncratic. Hence new competitors can imitate the new technology and their entry drives the prices to competitive levels. Clearly the prices of products

manufactured with a higher intensity of idiosyncratic inputs ( $P_I$ ) are higher than the prices of the products manufactured with a low intensity of idiosyncratic inputs ( $P_G$ ). Search processes might also be directed towards those knowledge outcomes that are much easier to protect through IPRs.

Equations (2) and (3) can be combined into the traditional frontier of possible production:

$$(6) Y_G = e(Y_I)$$

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-intensive technology ( $P_G$ ) to the prices of the products manufactured with a new idiosyncratic-intensive technology ( $P_I$ ). The equilibrium is found where:

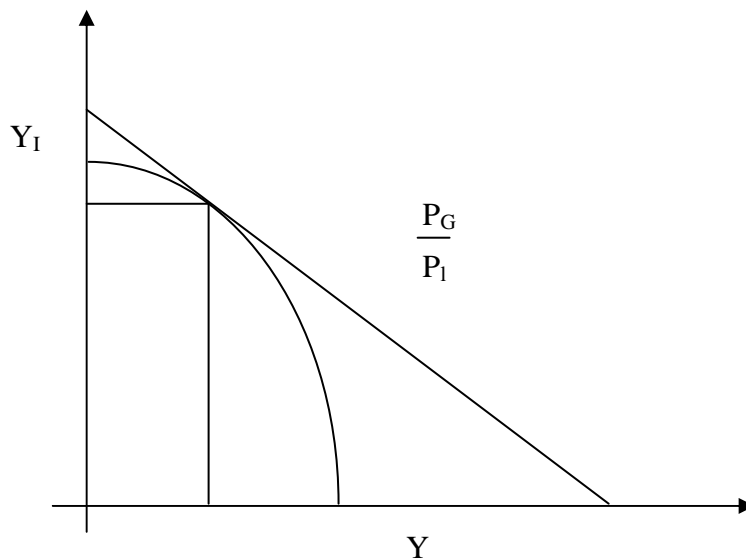
$$(7) d Y_g / d Y_I = P_I / P_G$$

Clearly there are stronger incentives to select the mix with more biased technologies, than generic ones. A simple geometric exposition can help to grasp the point. As is shown in Figure 1, the shape of frontier of production possibilities which considers the trade-off between the levels of output  $Y_I$  which can be attained by introducing a new technology that uses locally abundant and idiosyncratic production factors intensively and the levels of output  $Y_G$  that can be attained by using a new technology which uses generic production factors, is clearly asymmetric. The idiosyncratic-intensive technology is more efficient than the generic-intensive one. Moreover the slope of the isorevenue, much smaller than 1, reflects the positive effects for idiosyncratic-intensive innovators of the price asymmetry with respect to imitators, which do not have access to the same idiosyncratic production factors. Idiosyncratic-intensive innovators can charge higher prices and retain larger price-cost margins than generic-intensive innovators. The combination of both effects is reflected by the optimization that clearly favors the introduction of technologies based upon the more intensive use of locally abundant and idiosyncratic production factors.

Firms able to select their technological innovations so as to introduce a bias in favor of the creation and subsequent intensive use of idiosyncratic production factors have a larger mark-up because of three factors: a)

lower production costs, b) higher product prices, c) barriers to entry and imitation lasting for a longer stretch of time.

FIGURE 1. OUTPUT AND REVENUE MAXIMIZING INCENTIVES TO USE OF IDIOSYNCRATIC INNOVATIONS INTENSIVELY



In short, the generation of technological knowledge and the eventual technological change is directed by: a) the costs-reducing use of locally abundant production factors; b) the profit-increasing use of local idiosyncratic production factors. According to the value and weights of these parameters the characteristics of new knowledge and the direction of technological change can be assessed ex ante.

The embodiment of technological knowledge into a selective and directed technological change that takes into account the local conditions of both product and factor markets makes it possible to appropriate the stream of benefit associated with its generation.

#### 4. DYNAMIC IMPLICATIONS: INNOVATION CASCADES

An important step towards a dynamic extension of the analysis can be made when the origins of the local supply of idiosyncratic factors is investigated. The introduction of technological innovations in upstream industries is a major source of the local supply of such idiosyncratic factors. Firms active in downstream industries and clustering in the same geographic space can take advantage of the introduction of innovations in upstream industries. Proximity, both in knowledge and geographical space, favors the early adoption of new production factors and makes

easier user-producers interactions. Co-localized firms have a better opportunity to take advantage of upstream innovations than remote firms. Co-localized firms have a privileged access to the new technologies both as adopters and adapters.

The supply by upstream innovators of new products, that can become production factors, provides the opportunity for downstream users, that are co-localized and/or have privileged access to these innovations, to take advantage strategically of their localized availability and stimulates them to generate new technological knowledge and eventually introduce new technologies that use them intensively.

An understanding of the effects of pecuniary externalities upon the direction of technological change makes it possible to get a better grasp of the feedback dynamics of the process that leads to cascades of innovations. The selection of new directional technologies that make an intensive use of innovative production factors provided by upstream industries at favorable conditions increases their derived demand for upstream suppliers. Hence, the possibility of increasing the division of labor in upstream industries is further enhanced and consequently the specialization and the incentives and opportunities to introduces innovations in upstream industries. The process will engender new pecuniary externalities with the continual interaction between upstream and downstream innovation activities.

Innovation cascades emerge as soon as the supply of idiosyncratic production factors is no longer regarded as exogenous or static, but rather the endogenous result of the interaction among innovative firms active in different layers of the filieres and value chains. Innovation cascades are the result of the efforts of innovative users to take advantage of the new technologies being introduced by innovative suppliers. The changing conditions in downstream markets will in turn engender further feedback for upstream suppliers. The complementarity of downstream and upstream innovation processes is necessary for innovation cascades to take place.

The provision of advanced services can play a major role in this context, well beyond, the limits specific vertical filieres. Fransman (2008) provides wide evidence on the key role of the technological advances in information and communication industries in stirring the introduction of an array of derivative innovations in a range of downstream industries and in the organization of inter-firm and intra-firm relations in the US economy. The growth of venture capitalism in the US has proven to be

the source of a major competitive advantage for innovative start-up companies and especially for scientific entrepreneurship (Antonelli and Teubal, 2008).

## **5. CONCLUSIONS AND STRATEGIC IMPLICATIONS**

The contributions of the paper are two-fold: i) to show that the localized technical change approach integrates and expands key elements of the theory of the firm of Penrosian tradition; ii) to propose an outline of normative analysis. Let us consider them in turn.

The integration of the resource based theory of the firm into the traditional analysis based upon the notion of localized technological knowledge yields important dynamic results when the analysis focuses on the determinants of the selective generation of new technological knowledge, as the result of identifying and exploiting the sources of external knowledge and the introduction of biased technological change that favors the intensive use of production factors that are idiosyncratic to each firm. The new analysis regarding the distinction between learning and knowledge and the new understanding regarding the key role of pecuniary externalities in localized knowledge appropriability emphasize the strategic role of the direction of technological knowledge and provides an economic foundation for the notion of distinctive competence of the firm, much used in management and strategic analysis.

Learning is a necessary, but not sufficient condition for the generation of new knowledge. External factors play a key role both in the intentional generation and exploitation of technological and organizational knowledge. The combined effect of internal learning, external knowledge and the conditions for exploitation associated to the intensive use of idiosyncratic factors by means of introducing biased technological change cum intentional decision-making, provide key inputs to understanding the path dependent and idiosyncratic features of the knowledge generated by the firm as the basis for building its distinctive competences.

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 and selective strategies are necessary in order to generate new knowledge. Technological knowledge intentionally generated by firms has a strong idiosyncratic character that is influenced both by the

characteristics of internal learning processes and by the characteristics of local factor and product markets.

In order to increase knowledge appropriability firms have a clear incentive towards the generation of technological knowledge that makes it possible to intentionally choose the direction of technological change. The downstream vertical integration into specific production processes qualified by the intensive use of locally and possibly internal production factors, that are highly idiosyncratic and hence cheaper for a limited number of users, favors the productivity of new directed technologies and reduces the risks of imitation by rivals who do not have access to the same factor markets. Such production factors are idiosyncratic to the innovating firm by locational factors or directly as the result of them being intentionally created by each firm.

Pecuniary externalities make it possible for firms to appropriate technological knowledge embodied in processes and products better. The strong positive effects in terms of reduced production costs and increased knowledge appropriability stemming from the intensive use of idiosyncratic – either locally available or internally created- production factors provide a clear incentive to select the direction of knowledge generation. The opportunities for localized knowledge appropriation provided by pecuniary externalities become a powerful mechanism to direct not only the introduction of new technologies but also the generation of new technological knowledge. A direct feedback emerges between knowledge exploitation and generation strategies.

The identification of the sources of the idiosyncratic production factors which are more convenient to use intensively becomes a powerful guideline and focusing mechanism that directs the technology strategy of innovative firms. The result is that firms create and exploit a broader distinctive competence which includes its geographical and industrial localization of which the firms are able to make a strategic and dynamic use of it.

The normative implications of our analysis both for economic policy and strategic management are clear. Much attention has been devoted to intellectual property right regimes as an effective way to increase the appropriability of knowledge as a good per se. The current debate on intellectual property right regimes seems to assume that there are no other ways for firms to appropriate their knowledge. With weak intellectual property rights regimes there are low incentives to generate new knowledge. Temporary monopolistic rents provided by patents do reduce

static efficiency but yield dynamic efficiency. This analysis does not take into account other important means of knowledge appropriation and exploitation. Embodied appropriability of knowledge has received little attention in the recent literature. Yet the appropriability of knowledge can be strengthened by means of its embodiment either in incumbent corporations that enjoy barriers to entry and hence can delay the imitation of their innovations, or by means of its embodiment in products that make intensive use of idiosyncratic production factors. An understanding of the working of embodied appropriation of knowledge should favor the introduction of non-exclusive property rights that help the dissemination of new knowledge and yet provide inventors with the right to some levels of royalties (Antonelli, 2007b).

From a strategic management viewpoint the analysis elaborated in this paper confirms that firms have a variety of tools to increase the appropriation of their technological knowledge. When the protection provided by intellectual property rights regimes is weak, firms can rely upon complementary assets over which they retain some levels of exclusive command (Teece, 2000).

From a technology analysis viewpoint this paper has shown that the intentional and strategic direction of technological change is influenced by the identification of idiosyncratic production factors. Firms have a strong incentive to identify the local availability of idiosyncratic production factors and to direct the introduction of technological innovations so as to make an intensive use of them. This strategy seems most effective for small firms which cannot take advantage of economies of size which are a source of barriers to entry and hence to imitation and more generally it is also effective when the levels of 'natural' appropriability of knowledge are low and intellectual property right regimes are weak.

Finally it is clear that the availability of idiosyncratic production factors is not exogenous, neither it is static. Idiosyncratic inputs are often the result of upstream production processes that downstream firms are able to use quickly. The provision of technological innovations by upstream producers can become a major opportunity for downstream users to build a competitive advantage, provided they are able to adopt the new technologies and to direct their technological strategies at the right time so as to use them creatively, adapting them actively to their own specific production and market conditions.



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