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THE USEFUL APPLICATION OF KNOWLEDGE: AN INTRODUCTION

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Schumpeter (1928) laid down not only the basic association between innovation and (transient) monopoly due to the non-appropriability of knowledge, but also the tradition of analysis according to which invention is the basic source of externality and growth of economic systems (Schumpeter, 1928). These two strands of analysis have relevant effects on the understanding of the firm and the working of the system at large. Let us analyze them in turn.

The identification and appreciation of the wide range of externalities that knowledge is able to yield can be regarded as one of the main achievements of the economics of knowledge (Adams, 2006). The identification of technological spillover by Zvi Griliches (1979) can be considered a starting point in this line of investigation. Knowledge spillovers are nothing else but the positive side of the limited appropriability first identified by Schumpeter and named by Arrow.

The discovery by Zvi Griliches of the positive aspects of limited appropriability in terms of knowledge spillover had a major impact. His intuition helped economists to appreciate–by means of the technology production function where knowledge enters the production function as a fundamental input next to capital and labor–the positive effects of knowledge spilling from third parties on the actual production costs of each agent in the system. The discovery of knowledge spillovers provided the foundation for the new growth theory. Technological knowledge appears to be ‘better-than-standard-economic-goods’ to the point that an increase in total factor productivity growth can be accounted for by the amount of knowledge that, like a pure externality, spills from inventors to third parties. Due to limited appropriability, inventors appropriate only a part of the benefits of the new knowledge, but knowledge spillovers benefit an increase in the total factor productivity of the whole system. Griliches's contributions paved the way to the new growth theory where technological knowledge spilling from one firm in the atmosphere contributes to the technological advance of all the other firms. The system enjoys increasing returns but each firm is, at each point in time, in equilibrium in product markets characterized by monopolistic competition and increasing product variety (Romer, 1994).

In this approach external technological knowledge has been viewed as an augmenting and facilitating factor in the introduction of technological innovations. Such a role has taken the form of a ‘pure’ externality, that is, an unpaid production factor that enters freely into the production function of other firms. Knowledge externalities are not only pure but also global and broadcast. Technological knowledge is expected to spill freely across international markets and industrializing countries can imitate it with no costs. No dedicated and intentional communication channels are necessary for the dissemination of knowledge (Adams, 2006).

Empirical evidence shows that total factor productivity growth takes place with considerable heterogeneity across historic times and at each point in time, across countries, regions, industries and firms. It seems to be very difficult, especially at the microeconomic level of analysis, to reconcile the evidence provided by the cliometric and contemporary economic evidence with the steady homogeneity of the representation of the new growth theory (Metcalfe, 2002).

Consolidation of the alternative view that knowledge spillovers do not spill freely in the atmosphere and their access and use imply substantial costs due to their strong tacit and sticky content that makes it very difficult to identify, learn about and use without major efforts and interaction between users and the original possessors and inventors opens up a new perspective for understanding of the links between knowledge, productivity growth and economic growth (Mansfield, Schwartz, Wagner, 1981).

Because knowledge does not spill in the atmosphere, firms can actually generate new technological knowledge according to the specific and highly idiosyncratic conditions of actual access and use of external knowledge. Consequently total factor productivity can be explained as the result of the levels of knowledge externalities that stems from the combined availability of narrow and broad cast, pecuniary and pure, global and local, horizontal and vertical, inter and intra industrial knowledge externalities. In the new economics of knowledge, in fact, internal knowledge and external knowledge are two complementary and indispensable inputs for the recombinant generation of knowledge as an output and consequently an input into the generation of all the other goods (Weitzman, 1996 and 1998). Total factor productivity will be larger when and if the cost of knowledge is below equilibrium levels because of the pervasive and effective role of knowledge externalities. This approach enables to account for the great variance of total factor productivity growth across countries, regions, industries, firms and most importantly historic times. The actual conditions of access and use of technological knowledge in fact are far from homogeneous: they are highly heterogeneous and vary across economic space and time. The actual levels of knowledge externalities are highly idiosyncratic. Total factor productivity growth can be understood only taking into account their varying levels (Antonelli, 2013).

As a result of this alternative approach, a rich exploration of the different types of knowledge externalities takes place: knowledge externalities are better appreciated as being narrow/broadcast, pecuniary and pure local and global, horizontal and vertical, intraindustrial and interindustrial.

Broad versus narrow cast knowledge externalities

The analysis of the mechanism by means of which knowledge externalities spread and specifically the understanding of the processes by means of which firms can access and use external knowledge as an input both for the production of new knowledge and all the other goods enables to elaborate a further, crucial distinction between broad versus narrow cast knowledge externalities. The dissemination of broadcast knowledge externalities in the system is unlimited and instantaneous and does not require any dedicated channel: knowledge in this case is very close to information. When knowledge has a strong tacit and sticky content, instead, knowledge externalities are rather narrowcast. Their dissemination can take place only by means of dedicated channels. As Arrow (1969:32) notes: "The transmission of the observation or of the revised probability judgments must take place over channels which have a limited capacity and are therefore costly." Dedicated knowledge ommunication channels are necessary to enable knowledge interactions between knowledge holders and perspective users. They can be both direct and intentional as well as indirect and preterintentional: transactions among two parties are often implemented by knowledge interactions. Mobility of skilled personnel is an effective knowledge communication channel where knowledge interactions are indirect. The mobility of skilled personnel takes often place without the agreement of the former employer. Knowledge communication channels can be implicit or explicit with the creation of research consortia (Branstetter and Sakakibara, 2002),

Pecuniary or pure knowledge externalities The acquisition and use of external knowledge spilling into the atmosphere requires substantial efforts by perspective recipients in terms of screening, identification, uncoding and recoding, and, most importantly, learning. An understanding of the sticky aspects of tacit knowledge makes it possible to grasp the crucial role of user-producer interactions in the generation of new technological knowledge and in the introduction of technological innovations (Von Hippel, 1988). In turn, knowledge interactions are not free and require the participation of both parties. In sum, external knowledge has a cost. When this cost is lower than the cost of its reproduction, pecuniary knowledge externalities are found. Empirical evidence regarding the relevant absorption costs that are needed to actually benefit knowledge spillovers have helped to appreciate the role of both the systemic conditions and the intentional strategies of actors in qualifying the access to existing knowledge and stressed the role of pecuniary knowledge externalities–as opposed to pure externalities–in shaping the actual costs of the use of the stock of knowledge. Since pecuniary knowledge externalities can measure the actual costs of external knowledge, they can actually account for the differentiated rates of productivity growth across regions, countries and firms (Cohen and Levinthal, 1990; Antonelli, 2008).

In the new context of the knowledge generation function, knowledge is twice an input: an input not only for the generation of all the other goods, but also the generation of new technological knowledge. The acquisition and use of knowledge spillovers, stemming from the stock of existing knowledge, require dedicated activities. Hence, the higher absorption costs are and the lower the pecuniary knowledge externalities are, the lower the positive effects of the amount of knowledge available. This in turn implies that a reduction in the cost of knowledge as an input, not only in the knowledge generation function of new technological knowledge, but also in the technology production function of all the other goods, can only take place when absorption costs are low (Antonelli, 2013).

Horizontal and vertical knowledge externalities. The sources of knowledge externalities matter: it is important to discriminate between knowledge externalities and whether they flow vertically from upstream producers of capital and intermediary inputs to downstream users embodied in machinery and in direct knowledge interactions, or from downstream users, or horizontally among competitors. Upstream vertical flows of external knowledge channeled both by transactions and interactions have positive effects mainly on the introduction of process innovations whereas downstream vertical flows of external knowledge have positive effects mainly on the introduction of product innovation. The horizontal flows of external knowledge spilling horizontally from competitors also have a stronger positive effect on the introduction of product innovations. External knowledge can flow horizontally within the same industry among competitors and vertically across industries. Horizontal knowledge spilling from competitors active in the same product market seems better able to contribute to the generation of new technological knowledge directed towards the introduction of product innovations. Here, external knowledge consists of the reciprocal borrowing and use of technological knowledge produced by each competitor who is able to imitate and implement the innovations introduced by the other firms engaged in the same innovation race. Technological knowledge flows vertically among firms within value chains and across industries. Transactions between suppliers and customers of capital goods and other intermediary inputs are a primary source of embodied technological knowledge which is able to affect the innovation process of downstream users. Customers of advanced capital goods that embody new technological knowledge can take advantage of learning by using and introducing new technologies in their production process. The intensity of purchases has a positive effect on the likelihood that customers introduce process innovations.

Global and local knowledge externalities. Jaffe (1989) stresses the local character of knowledge externalities. He explores the effects of academic research on the generation of technological knowledge by firms and shows that only firms that are geographically close to each other are actually able to take advantage of the knowledge spilling from the academic system. He is able to identify significant effects of academic research on the number of patents filed by firms particularly in the areas of drugs, medical technology, electronics, optics, and nuclear technology. Once again, Jaffe took one step forward by suggesting that academic research may actually induce the R&D activities of colocalized firms. According to this line of analysis, since proximity plays a central role in this context, knowledge externalities are intrinsically local, as opposed to global. Since technological knowledge is intrinsically localized in the system, the actual amount of knowledge that can be generated by each agent and the system at large is strongly influenced by the structural characteristics of the local system in which firms are embedded. Technological knowledge is inherently rooted in the local system in which firms are based because it is embedded in the network structure of interactions-cum-transactions that shapes the access to knowledge externalities (Antonelli, 2011). Geographical proximity helps knowledge interactions take place and makes them effective. Proximity and agglomeration help to implement the working of the personal networks that support knowledge interactions whereas distance hinders knowledge interactions that need to take place over time and require repeated occurrences to be established. Firms can only exploit external knowledge locally through the accurate planning of a strategy aimed at acquiring bits of knowledge that are complementary to their own competences. In this perspective, external knowledge, as a necessary input for the generation of new technological knowledge, is acquired at costs that include a variety of efforts and dedicated activities such as screening, identification, interaction and purchase, and eventual absorption. Such costs increase with distance and across economic systems (Branstetter, 2000). This approach is contrasted by the evidence provided by Coe and Helpman (1995), further enriched and qualified by Keller (1997 and 2010) who suggests that the flows of international trade and foreign direct investments are major carriers of knowledge spillovers and the larger is the international exposure of a country and the larger are the opportunities to benefit from global knowledge spillovers. Cultural and institutional proximity across countries help the dissemination and absorption of global knowledge externalities. In sum, knowledge externalities are both global and local. According to the structural conditions of the system in which firms are embedded, and its degree of openness to international markets, the actual access to external knowledge differs as much as the actual levels of knowledge externalities that firm can take advantage of. The availability of low cost external knowledge reflects both the quality of the local governance mechanisms and the levels of knowledge connectivity internal to the system in which firms are localized and with the other systems with which each system interacts.

Inter or intraindustrial knowledge externalities An appreciation of the diversity of technological knowledge(s) helps to identify the role of Jacobs' knowledge externalities. The variety of knowledge items available in a given context and the composition of its knowledge base have a direct impact on the amount of knowledge that can be generated and, more specifically, on its characteristics. Countries and regions with a higher degree of related variety and a proper composition of their knowledge base enjoy more learning opportunities and consequently more local knowledge spillovers. Variety at the regional level, variety qualified in terms of knowledge coherence and relatedness, plays a positive role in favoring the generation of new technological knowledge.

Are knowledge externalities endogenous? The Schumpeterian approach that impinges on the framework elaborated by Schumpeter (1947a and b) helps to understand that knowledge externalities are endogenous. According to Schumpeter (1947), firms are often exposed to mismatches between the plans needed to organize their current business and the actual conditions in product and factor markets. Their reaction can be adaptive (or passive) and creative. Passive reactions consist of textbook switching activities on the existing maps of isoquants and adjustment of prices to quantities and vice versa. Passive reactions take place when firms cannot take advantage of knowledge externalities. The properties of the system in which firms are embedded play a crucial role in assessing the access and use conditions of external knowledge. The systemic determinants of the cost of technological knowledge in turn have important consequences on the Schumpeterian creative reaction. Following Schumpeter (1947a and b), the introduction of innovations takes place when firms, caught in out-of-equilibrium conditions by the mismatch between expected and actual factor and product market conditions, are able to implement a creative, as opposed to adaptive, reaction. Their creative reaction can take place only if and when substantial knowledge externalities support the generation of technological knowledge that is needed in order to innovate.

Without knowledge externalities, in fact, firms may be able to change their techniques by moving on the existing map of isoquants, but they cannot introduce technological innovations. Without knowledge externalities, firms may increase the variety of their products and production processes, but cannot introduce productivity enhancing innovations (Antonelli, 2008). Their reactions to unexpected mismatches between expectations and actual conditions in both product and factor markets are creative when and if relevant knowledge externalities are available. Only with relevant knowledge externalities firms that try and react to mismatches that push them in out-of-equilibrium conditions can introduce actual productivity enhancing technological innovations (Antonelli, 2011). External knowledge is, in fact, indispensable to supporting creative reaction and actually introducing technological innovations. If the availability of knowledge externalities makes the creative reaction possible, it is also clear that the availability of knowledge externalities at time t supports the augmented generation of new technological knowledge at time t+1 and consequently, the creative reaction of firms. The generation of knowledge externalities is endogenous to the system.

Firms can actually produce more when they can access and use knowledge, as a necessary and indispensable input for the generation of new technological knowledge, at costs that are below equilibrium levels. Access to knowledge at costs that are below equilibrium explains the production of output above equilibrium, i.e. the residual. A large array of economic and institutional factors accounts for changes in the costs of accessing external knowledge. The same array of economic and institutional factors can account for the heterogeneity of total factor productivity growth across time, regions, industries and firms that the new growth theory could not explain (Antonelli, 2013).

A grasping of the crucial role of knowledge externalities and their breakdown into broad versus narrow cast, pure/pecuniary, vertical/horizontal, global/local, ,intra/interindustrial and exogenous/endogenous types is a major achievement in the economics of knowledge that has profound effects on the theory of the firm both with regard to its implications for an understanding of the use of knowledge in firm strategy and conduct and analysis of the dynamics of structural change at system level.

The new appreciation of knowledge cumulability and non-exhaustibility and the consequent static and increasing returns and knowledge externalities provides the resource-based theory of the firm with new important avenues for research and implementation.

The resource-based theory of the firm (RBTF) had implemented the view first elaborated by Edith Penrose (1959) that the firm is, above all, a bundle of competences and capabilities, mainly based on learning processes eventually implemented by formal research activities (Nelson and Winter, 1973; Wernerfelt, 1984). In the RBTF, the generation of the knowledge bundle comes before the production process: firms select the types of products and processes according to their specific learning processes and the existing bundle of internal competences and capabilities (Teece, Pisano, Shuen, 1997) in terms of appropriability, cumulability, coherence and tradability: the boundaries of the firms are defined by coupling their technological specialization and organizational competences (Winter, 2003; Brusoni, Prencipe and Pavitt, 2011).

The corporation is the great institutional innovation introduced in the US in the early XX century characterized by the full integration of the generation of technological knowledge into the internal organization of the firm and its exploitation by means of the continual introduction of technological innovations as an intrinsic component of its strategy (Chandler, 1962, 1977, 1990, 2002).

The stock of knowledge internal to each firm is its main source of competitive advantage. The larger is the stock of internal knowledge and the lower are the unit costs of the goods produced and the costs of further knowledge. Firms that are able to generate new knowledge and implement its internal use as an input for the generation of further knowledge can enjoy a long-lasting competitive advantage. The traditional RBTF has based for quite a long time its research agenda on the analysis of the static and dynamic increasing returns that stem from the internal stock of knowledge.

The understanding of the role in the knowledge generation process of its cumulability and non-exhaustibility, and the acknowledgment of its irreducible tacit content provide the foundations to grasping the key relationship between knowledge, increasing returns and asymmetric competitive advantages. Because of its tacit content 'inventors' can retain a partial control of the technological knowledge that they have been able to generate: inventors can enjoy partial appropriability. As a consequence they benefit of both static and dynamic increasing returns. Static increasing returns consist in the economies of density that stem from the application of the very same piece of knowledge to increasing quantities of goods. The costs of knowledge can be regarded as fixed costs that can be spread over unlimited quantities of goods. As a consequence average unit costs decline with the size of production.

Large firms with a large stock of knowledge can benefit of substantial costs advantages with respect to the competitors that cannot spread the cost of knowledge on the same quantity of goods. Dynamic increasing returns consist in the use of the existing stock of knowledge as an input to the generation of further knowledge. Firms that have been able to generate a piece of knowledge and can retain some appropriability on it, can take advantage of substantial sunk costs. The costs of the new knowledge will be just incremental. Competitors that cannot rely upon the internal stock of knowledge will bear the full costs of the new piece of knowledge. The pervasive role of knowledge cumulability and non-exhaustibility is at the origin of: a) relevant static increasing returns that accounts for the persistence of substantial cost asymmetries in the market place that favor incumbents; b) relevant dynamic increasing returns in the generation of knowledge that accounts for the persistence of innovative activities. The earlier generation of knowledge and introduction of innovations favors the further generation of and the introduction of further innovations. Knowledge cumulability and non-exhaustibility are at the origin of non-ergodic processes (Antonelli Crespi Scellato, 2012, 2013, 2015).

After much emphasis on the role of the internal stock of knowledge, the appreciation of the pervasive role of knowledge externalities has enabled to elaborate the broader view that the firm is primarily a 'system integrator' that combines internal and external knowledge to generate new technological knowledge (Winter, 2003; Kogut and Zander, 1992). The definition of the firm is now jointly influenced by the characteristics of the internal competence and the system in which it is embedded and specifically not only by the conditions of knowledge accumulation, but also by the conditions of knowledge exploration, and how they jointly shape the conditions for knowledge exploitation (March, 1991).

These results help us to appreciate the role, when defining firm strategies, of the variety of dedicated activities such as the screening of the myriad of possible sources of useful knowledge, their assessment and decodification, their matching with the internal sources that are necessary for their subsequent active inclusion and integration as inputs in the knowledge generation process, and the variety of tools through which external knowledge is sourced (user-producer interactions, mobility of personnel among firms, interactions with academic research), and also to discriminate between sources of external knowledge. In the new approach, the search for the proper match between types of external knowledge and their relative costs and innovation strategies has important implications for firm strategies. Firms will take into account the important differences in the actual access conditions and absorption costs of the different types of external knowledge, whether vertical upstream or vertical downstream and horizontal, when selecting their innovation strategies. The sources of external knowledge, whether horizontal, downstream or upstream vertical, influence not only the amount of new technologies being introduced, but also their types, whether process or product, and the organization of firms. Now even the boundaries of the firm as well as its innovation strategies are influenced by the characteristics of knowledge externalities (Patrucco, 2014a).

In the new RBTF, careful identification of the role of knowledge in the strategy of the firm, selection of the types of innovation, whether product or process, screening of the types of technological spillovers available in an economic system, and the architecture of relations within the corporation and with the networks of suppliers and customers are part of a single, integrated decision-making process. The feedbacks of 'active consumers' in the final markets, together with those of customers and providers in intermediary markets, and competitors in product markets, are all indispensable sources of knowledge (Bianchi, 1998). The actual availability of external knowledge influences innovation strategies as much the characteristics of the internal knowledge base, learning processes and kind of competences. The search for an accurate matching of types of innovations, types of organization and types of knowledge becomes the key procedure for decision making (Patrucco, 2014b).

The understanding of the combined effects of the access and use of pecuniary knowledge externalities and the repeated use of the internal stocks of knowledge helps accounting for the levels and the rates of increase of total factor productivity, both at the firm and the system level. Because of the idiosyncratic characteristics of knowledge such as cumulability, non-exhaustibility, the limited appropriability that disseminates knowledge externalities through the system, its dual role of both an input and an output, the generation of new knowledge can take place at cost conditions that are below equilibrium levels. When the costs of access and use of external knowledge are especially low and the internal stock of knowledge are complementary with the external sources, and can repeatedly used, new knowledge can be generated at incremental costs that are below average costs. The divergence between average and incremental knowledge costs may be at the origin of the growth of total factor productivity. Equilibrium levels of output for given amount of inputs are in fact estimated assuming equilibrium conditions. The larger the gap between knowledge equilibrium costs and actual knowledge costs and the larger may be total factor productivity (Antonelli, 2013).

The appreciation of the combined effects of the repeated use of the internal stock of knowledge and the access to the array of knowledge externalities however is *a necessary but not sufficient condition* for the eventual introduction of innovations and the actual increase of total factor productivity. Technological change takes place and hence total factor productivity actually increases only when two conditions jointly apply: i) the possibility to generate new technological knowledge at costs that are below equilibrium levels, and ii) the effort of firms to react creatively to mismatches between expected and actual market conditions and generate and use technological knowledge to introduce technological innovations. Neither condition alone is sufficient to understand the introduction of innovations. Firms that do not experience mismatches between the expected and actual conditions of product and factor markets are reluctant to engage in the innovation activities, even if knowledge externalities are available. In turn, the attempt of firms experiencing mismatches between expected and actual product and factor market conditions cannot become creative and hence lead to the introduction of technological and organizational innovations if knowledge externalities are not available. The analysis of the working of these to joint conditions can be implemented successfully with the notion of system emergent property (Antonelli, 2015).

The late Schumpeterian notion of innovation as a creative response is at the heart of this approach. According to Schumpeter (1947a and b; Antonelli, 2011), firms are affected by bounded rationality and limited foresight hence are rarely able to foresee the actual evolution of their product and factor markets. Yet firms must make plans based upon expectations.

When there is no mismatch between expected and actual product and factor market conditions firms are reluctant to engage in innovation activities. They are well aware of the radical uncertainty that characterizes the knowledge generation process and the actual outcome of the full range of innovation activities. The regret theory of Kahneman and Tversky (1979) applies very well to make clear how difficult it is to change the current way of doing business. Firsm can overcome their regret only when unexpected circumstances expose them either to major opportunities or to major problems. The decision to try and innovate is taken only when the reluctance to change is overcome by unforeseen prospects for high profits or major losses that are engendered by emerging mismatches between expcted and actual product and factor markt conditions.

The responses of firms to the changing conditions of their economic environment can be either adaptive or creative. Responses can be simply adaptive and consist just in traditional price/quantity technical (as opposed to technological) adjustments on the existing map of isoquants when firms are not able to generate appropriate amount of new technological knowledge and hence are not actually able to innovate. When, instead, the generation of new technological knowledge is possible, at costs that are below equilibrium levels, the reaction is creative: firms can face the unexpected changes by means of the introduction of technological and organizational innovations that change the map of isoquants.

In the approach that builds upon the legacy of the late Schumpeter, the undertaking of innovative activities including the generation of technological knowledge does not take place as a routine and it is not a spontaneous and automatic action. Firms are able to overcome their reluctance to engage in the risky activities associated with the generation of technological knowledge and the introduction of innovations only when two circumstances jointly apply: i) they are forced by unexpected market conditions, and ii) they find an external context that provides them with appropriate levels of pecuniary knowledge externalities (Antonelli, 2011 and 2015).

For given levels of current research and learning efforts, the size and fungibility of the stock of knowledge internal to each firm, and the structural and institutional characteristics of the system that make pecuniary knowledge externalities available, cause and qualify the reaction of firms and make it actually creative, favoring the generation of technological knowledge at costs that are below equilibrium and the eventual introduction of productivity enhancing innovations. Productivity enhancing innovations are the result of the creative reaction of firms that emerge when pecuniary knowledge externalities are actually available. The amount of knowledge externalities and interactions available to each firm influences their capability to generate new technological knowledge, hence the actual possibility to make their reaction adaptive as opposed to creative and able to introduce localized technological changes. When the access conditions to the local pools of knowledge make possible the actual generation of new technological knowledge and feed the introduction of innovations, actual gales of technological change may emerge.

The generation of new technological knowledge induced by the attempt of firms to try and cope with the unexpected changes in product and factor markets by means of a creative reaction with the introduction of technological and organization innovations, is itself the endogenous cause of both: i) the increase of the size of the stock of knowledge internal and external to each firm; and ii) further unexpected changes in product and factor markets that induce new further reactions. Both knowledge externalities, market unexpected changes and technological changes are fully endogenous to the system. Technological knowledge and technological change are emergent system properties (Antonelli, 2011).

The understanding of knowledge as an emergent system property has guided the radical re-organization of the specialization of advanced countries since the end of the 20th century (Machlup, 1962). Advanced economies facing the twin globalization of product and capital markets have learnt how to take advantage of the endogenous regeneration of knowledge externalities by focusing on the role of knowledge as the basis of their participation in the international division of labor (Antonelli and Fassio, 2014). Advanced economies experienced at the end of the 19th century, the twin introduction of a radical technological change centered on the gale of information and communication technologies and a major structural change based on the emergence of the knowledge-intensive business service sector coupled with a drastic reorganization of the manufacturing industry centered on knowledge-intensive technologies (Stiroh, 2002). The shift from the manufacturing to the knowledge economy implies the increasing centrality of the role of knowledge as a final product, a capital good and an intermediary input (Buera, Kaboski, 2012; Shearmur, Doloreux, 2013). Advanced economies not only specialize in the production of knowledge-intensive services, but, within their economic systems, skilled labor substitutes blue-collar labor as much as intangible investments complement tangible ones (Abramovitz and David, 1996).

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