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Why is Technological Innovation Locally Concentrated? A Theoretical Review

Bi Goli Jean Jacques Iritié[1]

[1] Département de Gestion Commerce et Economie Appliquée, Laboratoire Droit, Economie et Gestion, Institut National Polytechnique Félix HOUPHOUET-BOIGNY, Yamoussoukro, Côte d'Ivoire

Correspondence: Bi Goli Jean Jacques Iritié, Département de Gestion Commerce et Economie Appliquée, Laboratoire Droit, Economie et Gestion, Institut National Polytechnique Félix HOUPHOUET-BOIGNY, B.P. 1093 Yamoussoukro, Côte d'Ivoire. Tel: 225-07-7986-5058. E-mail: jeanjacques.iritie@inphb.ci

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Abstract

In this paper, we provide a theoretical overview of the reasons behind the concentration of technological innovation in some areas. To do so, we first examine the issues of innovation as established by macroeconomic theories of growth then we discuss the incentives for its production according to market structures. Then, using an approach based on the economics and management of knowledge, we analyze the mechanisms and dynamics of the co-localization of innovative industries through the results of theoretical models of industrial organization. Specifically, we show that the localization of innovation is favored by the presence of knowledge externalities, especially of a tacit nature, and by the sharing of indivisible costs (e.g., technology platforms, clean rooms, road networks, etc.). It is also explained by strategic gains associated with R&D cooperation, such as informational incentives linked to the local ecosystem and the improved performance of technological agreements between firms belonging to the same epistemic community and located within an innovation cluster.

Keywords: Increasing returns, localized knowledge externalities, indivisible costs, technological infrastructures, R&D cooperation, informational incentives, epistemic communities

1. Introduction

Over the past two decades, industrialized countries have been facing changes in international industrial organization. New forms of industrial organizations based on the knowledge economy are emerging (Iritié, 2012; Iritié, 2018). Interest in creativity and technological innovation is growing, particularly in scientific and academic circles, as well as among public decision-makers around new industrial incentive policies. The specific feature of these new industrial schemes is their focus on territories and spaces. The emphasis on territories is based on the idea that they can facilitate the coupling of innovation, research, and industry, and make industries more competitive.

In Europe, these forms of innovation production organizations are also a response to the so-called Lisbon strategy adopted in 2000 by the European Council, whose aim was to make the European economy the most competitive and dynamic knowledge-based economy by 2010 (Rousseau & Mirabaud, 2008). It is in this context that several countries have developed innovation clusters as industrial policy strategies in Europe (Ketels, 2004). Examples include the Basque clusters in Spain specializing in household appliances and automobiles, the German cluster called Kompetenznetze, which is particularly active in high-tech sectors such as biotechnology and nanotechnology, the Medicon Valley which is a model of successful cooperation between the Danes and their Swedish neighbors in biotechnology and pharmaceuticals, the Italian technology districts and the French Minalogic competitiveness cluster specializing in micro-nanotechnology and embedded software on chips in the Rhône-Alpes region (Iritié, 2018).

Outside Europe, there are several other examples around the world with various appellations, such as Technopark, Science Park, Smart City, etc. Examples include UVU Africa (South Africa), Dubai Silicon Oasis (Dubai), Singapore Science Park (Singapore), Akwa Ibom Science and Technology Park (Nigeria), Silicon Wadi (Israel), Shenzhen High-Tech Industrial Park (China), EPFL Innovation Park (Switzerland), Hanshin Industrial Region (Osaka-Kobe, Japan), Technopolis (Rabat, Morocco). All this enthusiasm for clusters-based technological innovation is inspired and driven by the world-famous success of Silicon Valley in California, USA. It is true that innovation is seen at the firm level as the cost of surviving in the market (Kline & Rosenberg, 1986) and the main driver of economic growth (Solow, 1956; Romer, 1986). However, the reasons for the recent stronger and more general trend of polarization of innovative and collaborative knowledge production industries within territorial spaces deserve to be analyzed. Why is the territorial dimension becoming increasingly important in strengthening the competitiveness of innovative industries? Are there specific advantages linked to the localization of innovation? If so, what are they?

The aim of this study is to analyze the reasons that explain the concentration of innovation activities in given areas. To do so, we review theoretical literature in the fields of economic growth, industrial economics, and knowledge economics. This review shows that the localization of innovation is favored by the presence of increasing returns, knowledge externalities, the sharing of indivisible costs, and the strategic gains linked to R&D cooperation between firms within epistemic communities localized within an innovation cluster.

The rest of this paper is organized as follows. In section 2, we discuss the economic issues of innovation. In section 3 we analyze the reasons for the polarization of innovative activities within territories, and finally, in section 4 we conclude the paper.

2. Innovation, Growth and Market Structure

The macroeconomic analysis considers innovation to be the main driver of economic growth. In his seminal paper "A Contribution to the Theory of Economic Growth", published in 1956, the economist Robert Solow showed that, due to diminishing returns on capital, capital accumulation can explain to some extent the start of growth, but not its long-term persistence. He concluded that the core of the economic growth observed in the United States between 1909 and 1949 was exogenous to the productive system. Solow (1956) argued that the residual exogenous factor explaining around 87.5% of labor productivity growth was technological progress, or in a broader sense, innovation (or new knowledge) (Note 1). Solow's model, while demonstrating that innovation is the engine of growth, does not explain its origin. As a result, Solow paved the way for a great many studies aimed at identifying the main sources of technological progress. In the 1990s, this body of work gave rise to the endogenous growth theories pioneered by Romer (1986) (Note 2).

Endogenous growth assumes that perpetual growth is sustained by increasing returns to scale in the process of capital accumulation and that technological progress is endogenous. Innovation is not only at the heart of growth, but also above all a product of the economic sphere. It does not just fall from the sky but refers to resources invested in physical capital (Romer, 1986), public capital (Barro, 1990), human capital (Lucas, 1988), and technical and R&D capital (Romer, 1990; Romer, 1994). Endogenous growth theories recognize the essential role of knowledge in economic growth, considering its characteristics, notably its nature as a public good (Note 3). The accumulation of knowledge as a result of investment in R&D, training or learning and in infrastructure improves the efficiency of the additional capital invested and generates a further increase in the level of knowledge and technological progress. Therefore, the law of diminishing returns does not apply to knowledge. Innovation is becoming an additional factor of production at the macroeconomic level and is raising a lot of interest from politicians and scientists. Endogenous growth theories have thus opened a new perspective for the economic analysis of innovation and knowledge. However, they seem incompatible with the neoclassical assumptions of pure and perfect competition because of increasing returns. We know that, in the presence of increasing returns to scale, the remuneration of factors at their marginal productivity exceeds product or income (Note 4). Consequently, for knowledge to grow, its accumulation must be motivated by another remuneration mechanism, given that knowledge is difficult to appropriate once it has been produced. In other words, endogenous growth assumes that the dynamics of innovative activity inevitably generate imperfect competition in the private sector (Note 5). Indeed, the deliberate production of knowledge must necessarily provide the innovating firm with exclusive rent, a source of monopoly power. This contradiction from the neoclassical approach raises the question of market efficiency as a coordination mechanism, and of the most effective market structure to encourage innovation (Iritié, 2016). This leads us to analyze the microeconomic approach to the issues of innovation and the production of new knowledge.

The microeconomic analysis shows that firms involved in R&D are mainly motivated by the rent of innovation. The rent enables an innovative firm to cover fixed investments (often sunk costs) required for innovation activity. It represents the difference between the marginal cost and the selling price. However, product innovation (and even process innovation) is a source of monopoly, given the rent it generates for the innovator. The question then to be asked is: in order to encourage product innovation, should innovation be left solely to monopoly or oligopoly firms, or should perfect competition be favored in the name of economic efficiency in the neoclassical sense, in favor of consumers and the collective interest? One of the best-known theses on the relationship between market structure and the incentive to innovate is that of Joseph Schumpeter. Schumpeter (1942) defended the idea that large companies, and often monopolies, are the main driving force behind technological progress. In his view, because of their market power, monopolies are in a better position to invest in R&D (Note 6) than competitive firms. Monopolies are therefore a “necessary evil” to ensure the dynamic efficiency of the economic system. In contrast to the Schumpeterian hypothesis, advocates of competition assert that competitive markets discipline firms, encourage greater diversity in technological approaches and promote the spread of innovations by maintaining pressure on the prices of new products (Guellec, 2017).

Since then, the “Schumpeter conjecture” (Note 7) has been refined by several economists, the most important theoretical contributions being those of Arrow (1962), Gilbert and Newbery (1982), and Boone (2000). In analyzing the relationship between monopolistic market structure and the incentive to innovate, a distinction is made between a monopolist whose market power is persistent due to high barriers to market access, and one whose market power is more fragile and contestable by potential new competitors. The results show two opposing effects explaining monopolist behavior (Note 8):

The “replacement effect” highlighted by Arrow (1962) shows that in the case of process innovation, the pure incentive of a monopolist to innovate when not subject to potential entry is weaker than that of a competitive firm. Indeed, when it innovates, the monopolist replaces itself by earning a differential gain ($\Delta\pi^m$) smaller than a competing firm which would go from zero to a positive gain ($\Delta\pi^c$). So, the monopoly tends to rest on its laurels ($\Delta\pi^m \leq \Delta\pi^c$).

The “efficiency effect” highlighted by Gilbert and Newbery (1982) in the context of a deterministic auction model. Here, the monopoly (or incumbent) is under threat from a potential competing entrant. The firm that expresses a high willingness to invest acquires exclusivity of the innovation and exploits its benefits. If it’s the entrant, then it enters duopolistic competition with the incumbent and makes a duopoly profit $\pi_e^d = \Delta\pi_e$. On the contrary, if it is the monopoly that invests, it will remain a monopoly. In this case, its incentive to innovate $\Delta\pi^{t/e}$ will be equal, by definition, to the difference between its profit if it holds the innovation (π^m) and its duopoly profit if its rival acquires the innovation (π_t^d), i.e. $\Delta\pi^{t/e} = \pi^m - \pi_t^d$. The results show that $\Delta\pi^{t/e} \geq \Delta\pi_e$. This condition is known as the efficiency effect. In other words, the monopolist has more incentive to innovate and remain a monopolist than the entrant to become a duopolist. This efficiency effect explains the persistence of monopoly (Crampes & Encaoua, 2005).

In a patent race, the two effects overlap. It is then difficult to determine the dominant effect, which generally depends on the nature of the innovation (Tirole & Guesnerie, 1985). If the innovation is drastic, the replacement effect prevails, since the efficiency effect does not break the tie between the two firms. But, if the innovation is not drastic, the two effects are in competition, and the efficiency effect may dominate, especially if the innovation is very minor. These theoretical results invalidate Schumpeter’s position and show that competition is generally favorable to innovation incentives. However, they need to be put into perspective, as studies such as Boone’s (2000) theoretically show that beyond a certain threshold, the effect of competitive pressure on the incentive to innovate can be negative; even at the empirical level, the innovation-competition relationship in the market for products and services remains complex and imprecise.

Clearly, innovation will only take place if the innovator is protected from competition. The public-good nature of innovation, the effects of imitation, and high fixed costs justify protecting the results of R&D activities. The presence of knowledge externalities makes it difficult for the market to coordinate the production of innovation in a socially efficient way. Firms then underinvest in R&D, resulting in socially sub-optimal technological progress. It is therefore important for the social planner to encourage socially efficient production and to find appropriate ways of ensuring that the innovator appropriates the results of innovation activity. This trade-off characterizes much of what is at stake in innovation policy. In addition to traditional instruments such as public research and intellectual property rights (patents, trademarks, designs), the localization of innovative industries within innovation clusters is increasingly emerging as a new form of strategic organization and incentive for technological innovation. Empirical studies in the economic literature, such as Glaeser et al (1992), Martin and Ottaviano (1999), Martin (1999), and Riou (2003), support the close link between business localization and economic growth. In their view, localized forms of industrial organization perfectly share the stakes of R&D activities and could explain regional inequalities in growth.

3. The Issues of Localizing Innovation

The origins of industrial concentration can be found in Alfred Marshall’s observations towards the end of the 19th century. In England, Marshall observed a localized form of industrial organization, with many small firms involved in the production of a single good, each specialized in a particular production segment (Courlet, 2001).

Coordination between these firms is ensured both by the market (competition) and by cooperation and reciprocity. Marshall's intuition regarding this form of industrial organization is that there are "external economies" linked to the concentration and proximity of these firms. He called this mode of organization the "industrial district". This term was popularized a century later by Italian economists such as Becattini (1991). Marshallian external economies, the first explanations of the causes of localization of industry, indicate that there are gains to be had from concentrating activities in a particular area. The French economist Perroux was inspired by them when he developed his growth poles theory, which served as the basis for French regional development policy during the "Glorious Thirty" between 1945 and 1973 (see Perroux, 1957).

Marshall (1920) identifies three sources of agglomeration externalities: the local market for specialized skills, specific local equipment, and the network of direct interactions and information flows. Urban economists distinguish two types of agglomeration externalities: urbanization externalities, which refer to the simple co-localization of firms on the same site without their activities being linked, and localization externalities, which are reserved for firms with similar or complementary activities (Belleflamme et al., 2000). According to this typology, Marshall's externalities are localization externalities. Marshallian external economies are theoretically underpinned by three mechanisms: matching, sharing, and learning (Duranton & Puga, 2004). Indeed, a larger local market improves the quality or probability of the matching process between labor suppliers and job seekers and between buyers and suppliers. It also enables more efficient sharing of equipment, risks, and gains from specialization. Finally, it facilitates learning through the production, dissemination, and accumulation of new technological knowledge. However, it was not until the economist Paul Krugman's (1991) article "Increasing Returns and Economic Geography" that Alfred Marshall's intuitions were given a coherent theoretical body. Today, economic literature refers to this founding theoretical corpus, known as the "New Economic Geography ", to justify the agglomeration phenomena of economic activities in general, and those of innovative industries in particular; in the specific case of innovative industries, we speak of the "Economic geography of Innovation".

In this section, we first present the result of Krugman's (1991b) analysis. This study shows that the general arguments of economic theory justifying the localization of economic activities are the presence of increasing returns and transport costs (section 3.1). Then, in the following sections, we specifically discuss the challenges of localizing innovation activities, the essential elements of which are localized knowledge externalities (section 3.2), the sharing of indivisible costs (section 3.3), and finally, the gains from localized technological cooperation within innovation clusters (section 3.4).

3.1 Increasing Returns and Transport Costs

The theories of spatial location of factors of production or geographical economics are based on the work of Krugman (1991b). They use monopolistic competition models developed in industrial economics by Dixit and Stiglitz (1977) to introduce the role of firms' internal increasing returns and agents' preference for variety (Arthur, 1990; Fujita & Thisse, 1997; Riou, 2003) (Note 9). They aim to determine the trade-offs between the forces of concentration and dispersion and the resulting locations as a function of increasing returns, the level of transport costs, and the degree of competition on the market. Increasing returns can be explained, on the one hand, by the presence of internal economies (production indivisibilities due to the existence of fixed costs, greater productive efficiency of factors, acquired experience), and on the other, by the presence of external economies of Marshallian agglomeration.

Like theoretical models of localization, Paul Krugman's work emphasizes pecuniary externalities rather than solely positive technological externalities (Note 10). Krugman (1991b) considers an economy with two regions and two sectors of activity: agriculture and industry. Agriculture, a traditional activity, has constant returns; the peasant population is totally immobile and evenly distributed between the two regions. Industry, on the other hand, has increasing returns and produces differentiated goods in many varieties. A single firm produces each variety. The industrial activity can be located in either region, and workers can migrate from one region to another. Krugman (1991b) makes two assumptions about the structure of transport costs between the two regions: (1) the agricultural commodity is traded without transport costs, which guarantees a homogeneous price in both regions. (2) Conversely, the transaction of manufactured goods between regions generates transport costs in the form of Samuelson's iceberg, i.e., transport costs are included in the goods transported. In other words, for each unit of a manufactured goods transported from one region to another, only a fraction $\tau < 1$ arrives at its destination; τ takes the form of the inverse index of transport costs. The value of τ will determine the effect of transport costs on the choice of location for industrial activities, all other things being equal.

The mechanisms of Krugman's model define agglomeration and dispersion forces (Note 11) that shape the long-term localization equilibrium of the industrial sector (Riou, 2003). The magnitude of these forces depends on the value of transportation costs. For example, if a company decides to locate in one region, it will have to satisfy part of the demand in the other region, and therefore incur transport costs. To avoid these costs, which can be substantial, it may decide to locate in both regions. In this way, low transport costs encourage the concentration of activities in a single region. In addition, firms have an interest in locating where there are large markets to exploit increasing returns, just as it is optimal for consumers to migrate to the region producing the greatest number of varieties. The combination of these two forces can lead to two types of equilibrium: a symmetric equilibrium with an equal distribution of industrial activities in both regions or a core-periphery equilibrium where everything is concentrated in a single region. Agglomeration is more likely when there are increasing returns and low transport costs, all other things being equal. The existence of increasing returns is therefore essential to explain the polarization of economic activities in a location (Arthur, 1989). Bresnahan et al (2001) explain that increasing returns are linked to the mechanism by which entrepreneurship-driven regional growth takes off and becomes a lever for national development. Krugman's model has been criticized for its static nature. According to these critics, the model simply shows that an initial disturbance or "historical accident" can, under certain conditions of low transport costs and increasing returns, lead to an endogenous agglomeration process. The literature also identifies other sources of agglomeration, such as rent-seeking, natural factors (Rosenthal & Strange, 2004), entrepreneurship, culture and networks, and path dependence (Krugman, 1991a; Cortright, 2006).

3.2 Localized Knowledge Externalities

The theory of the economics of innovation shows that the allocation of resources by the arm's length market to produce new knowledge is socially sub-optimal (Arrow, 1962). The fundamental reasons for this social distortion are the intrinsic uncertainty associated with the activity of innovation and the public-good nature of the knowledge. As we pointed out earlier, the knowledge externalities generated are a source of increasing returns and imperfect appropriation of the benefits of innovation. Growth theorists, notably Romer (1986) and Lucas (1988), rely heavily on these characteristics of knowledge to justify the non-convexity of the production functions of economic activity and self-sustaining growth.

In the literature on economics and management of innovation, a distinction is generally made between two types of knowledge: codified, standardized, or articulated knowledge, and tacit, non-standardized, or contextual knowledge, which is difficult to formalize. According to the philosopher Polanyi (1962), tacit knowledge means "there are things that we know but cannot tell". In other words, a simple gesture often reveals more knowledge than we realize, and we are often unable to describe the knowledge revealed by our actions (Rix-Lièvre & Lièvre, 2012). The main difference between tacit knowledge and codified knowledge is that the marginal cost of transmitting codified information is made quasi-invariant by the telecommunications revolution, while the marginal cost of transmitting tacit knowledge decreases with social interactions and exchanges between co-localized agents (Audretsch & Feldman, 2004). In other words, the management and transfer of tacit knowledge relies essentially on face-to-face interactions and repeated contacts. Tacit knowledge therefore tends to be local. According to Wagner and Sternberg (1987), the ability of firms to acquire and manage tacit knowledge is a hallmark of managerial success and creativity. Tacit knowledge, also known as experiential knowledge, is not to be found in manuals, books, databases, or files. It is technical or cognitive and is produced by mental models, values, beliefs, perceptions, ideas, and hypotheses (Smith, 2001). Tacit knowledge is acquired, taught, and shared, for example, through knowledge fairs, learning communities, study missions, job changes, stories, and myths.

According to Almeida and Kogut (1999), the localized nature of knowledge externalities stems from the tacit dimension of knowledge. The highly contextual, tacit nature of knowledge would be very useful in the innovation process. It slows down the transmission of knowledge over long distances but instead favors the geographical proximity of firms, the polarization of innovative activities, and the promotion of R&D clusters (Torre, 2008; Madiès & Prager, 2008). Knowledge externalities (especially tacit knowledge) are the main issues when it comes to locating innovative industries in a particular area. However, this view of the importance of the tacit nature of knowledge and its perceived real effects in the dynamics of the localization process for innovative industries is challenged in the literature. The authors are really asking whether tacit knowledge externalities are spatially limited. If so, how are they transmitted? By what mechanisms are they measured, and what are their effects?

Research works on innovation economics have been primarily based firstly on estimating the knowledge production function proposed by Griliches (1979) and applied to local observation units to estimate the extent of knowledge externalities (see Jaffe, 1989; Audretsch & Feldman, 2004). For example, Jaffe (1989) uses this aggregate knowledge production function at the US state level to explore the existence of knowledge externalities from university research to firms, as well as their spatial extent. He uses a knowledge production function measured by the patent stock:

$$P_{ik} = \alpha(R\&D_{ik})^{\beta 1}(U_{ik})^{\beta 2}(U_{ik} * C_{ik})^{\beta 3}\epsilon_i$$

with *P* private patents (proxy for innovation), R&D is private research and development expenditure, U is university research expenditure and *C* the geographical coincidence (Note 12) between private and university research laboratories within the state; (*i*) is the geographical unit of observation, (*k*) the industrial sector and ϵ_i a random disturbance. The estimations show that the elasticities $\beta 1$, $\beta 2$ and $\beta 3$ are all significantly positive. In other words, university knowledge spills over and reaches other economic agents and private research laboratories, and that these externalities are localized. The author also shows that a state that improves its university research system will indirectly encourage local innovation through private R&D spending. Breschi and Lissoni (2001) question the robustness of Jaffe's (1989) results, which were confirmed by Acs et al. (1992) and Audretsch and Vivarelli (1994). Indeed, Audretsch and Vivarelli (1994) also point out that knowledge externalities from neighboring universities have a greater impact on small firms than on large ones. Audretsch and Feldman (1996b) show, however, that the effect of firm polarization is most marked during the early phases of the industrial life cycle, as congestion effects will appear during the phases of maturity and decline.

With the same aim of measuring the geographical dimension of knowledge externalities, Jaffe, Trajtenberg, and Henderson (1993) adopt a different method to that of Jaffe (1989). They consider that knowledge externalities leave traces in the form of patent citations. The patent citations contained in a new patent are markers and constitute a stock of prior knowledge making it possible to identify, at least partially, the trajectory of diffusion of innovations as well as their geographical character. More specifically, Jaffe, Trajtenberg, and Henderson (1993) use data from the US Patent Office to compare patent citation probabilities based on two samples: patent citations and control patents. For each patent citing an original patent, they randomly associate a control patent from the same technological field and period, but which does not cite the same original patent. The authors then test two hypotheses, null and alternative, using the standard Student's t-test:

$$H_0: P_{cit} = P_{cont}$$

$$H_1: P_{cit} > P_{cont}$$

with P*cit* the probability that the citing patent is in the same geographical unit as the original patent and P*cont* the probability that the control patent is in the same place as the original patent. The results show that citations are much more localized than control patents. In other words, the probability that cited patents and citing patents are co-localized is higher than the probability that cited patents and control patents are co-localized. The authors deduce that knowledge externalities are geographically constrained, and that this is the result of the tacit dimension of knowledge. This result is supported by those of Almeida and Kogut (1999) who tested the hypotheses of Jaffe et al. (1993) in the semiconductor sector. Almeida and Kogut (1999) also examined the nature of knowledge transmission channels. They showed that workers, and in particular the engineering network, are the vectors of knowledge transfer through inter-firm mobility. Based on these results, several studies confirm the important role of technological externalities in the localization of innovative industries. Audretsch and Feldman (1996a) show, for example, that innovation activities tend to be localized in industries with a high propensity to produce new knowledge, which is captured by industrial R&D, university R&D and skills. The same is true of several works using the patent citation method, which broadly support the positive influence of geographical proximity on patent citations in different regions of the world (see, for example, Duguet, 2005; Sing et al., 2010; Aldieri, 2011). However, according to Breschi and Lissoni (2001), the results of patent citation analysis constitute weak evidence for the existence of localized knowledge externalities. Moreover, the channels through which externalities are transmitted are not always explored in depth in these works, nor are their repercussions on productive activity.

Nevertheless, a few authors have analyzed the transmission mechanisms and effects of knowledge externalities. These have focused either on the importance of human capital (Zucker et al., 1994; Almeida & Kogut, 1999) or on the absorptive capacity of firms (Cohen & Levinthal, 1989, 1990; Cockburn & Henderson, 1998). For the former, knowledge does not propagate on its own but uses the transfer channels provided by skilled workers, especially when they move between firms and become localized. In other words, knowledge is incorporated into the human body. It is transmitted and localized through professional mobility. For the second group of authors, firms make efforts to take advantage of externalities, and in particular increase their internal R&D and skills to capture knowledge externalities from the environment (Hendrickx-Candela, 2001). Localization and proximity help reduce the uncertainty inherent to innovation activities and build the capacity to analyze and exchange tacit information; this is Cohen and Levintahl's (1989) notion of absorptive capacity. Knowledge externalities appear to be essential in justifying industrial localization policies. Knowledge externalities, especially tacit ones, are important in the production of innovation and drive firms, private or public research centers and laboratories, and local authorities to group together and work in synergy.

While the stakes involved in tacit knowledge externalities are considerable, some of the literature in the field of knowledge economics and management questions the distinction between tacit and codified knowledge (see Cohendet & Llerena, 1999, Foray, 2009, Breschi & Lissoni, 2001; Smith, 2001; Nonaka & Takeuchi, 1995, Tsoukas, 2003, Gourley, 2006; Rix-Lièvre & Lièvre, 2012; Hakanson; 2005; Kimble, 2013). The tacit nature of knowledge continues to be the focus of criticism. For the authors, the "tacitness" is not an intrinsic property of knowledge, but rather a property of the message transmitted and exchanged within an epistemic or cognitive community. It must be seen as the result of a system of incentives. According to Breschi and Lissoni (2001), tacitness and codification are mutually compatible, and all knowledge can be codified, communicated, or shared as a message over long distances by means of the media. For Smith (2001), codified knowledge is easily transformed into tacit knowledge when people cooperate, trust each other and willingly contribute their own valuable knowledge resources. Cowan et al. (2000) argue that knowledge can be codified for one person, tacit for another, and an impenetrable mystery for a third, depending on their capacity to absorb it. As a result, according to Boschma (2005), geographical proximity becomes irrelevant in justifying the localization and sharing of knowledge externalities, even tacit ones. Rather, it is cognitive or epistemic proximity that is necessary for the transfer of "tacit" messages.

We can broadly define an epistemic community as "a transnational network of knowledge-based experts interconnected by the respect of a procedural authority" (See Cowan et al., 2000; Cohendet et al., 2014 and Iritié, 2018 for further details). Epistemic proximity is a prerequisite for interactive learning and innovation, while geographical proximity becomes a mere facilitator. The notion of epistemic proximity is therefore gaining importance in the dynamics of knowledge creation and sharing, and is also of great interest in the process of localizing innovative industrial activities. In our view, access to and exploitation of tacit knowledge and expertise, whatever their degree of articulation and codification, is facilitated by the co-localization of an epistemic community in a given space. Håkanson (2005) and Cohendet et al. (2014) take a similar approach. Indeed, Cohendet et al. (2014) argue that epistemic movements and localized environments will continue to be the main basis for the formation of certain radical innovations in societies, as encounters between epistemic communities occur most of the time in a local context.

3.3 Sharing of Indivisible Costs

In addition to the knowledge externalities that generate direct gains, the localization of innovative technological activities is also explained by indirect gains arising from the sharing of significant fixed costs or local indivisibilities (Feldman, 1994; Feldman & Florida, 1994). Indeed, R&D requires heavy investment in infrastructure, such as clean rooms for experimentation, transport, and energy infrastructures, as well as external inputs to support innovation, such as academic institutions and specialized services. The spatial concentration of these so-called technological infrastructures and networks of complementary institutions encourages the polarization of innovative industries. Authors such as Ottaviano (2008) and Riou (2003) show that infrastructure improvement generates externalities and affect the geographic distribution of economic activities. Well-developed technological infrastructures are of greater benefit to small, innovative companies with few resources of their own, and enhance their capacity to innovate. Localization is therefore particularly beneficial to small businesses. Technology platforms are a perfect example of indivisibility in Europe. They bring together pooled R&D and innovation infrastructures and equipment, with the aim of offering services or resources. They are open to all actors in innovation clusters, and to small and medium-sized enterprises. They enable a community of users to carry out collaborative R&D, testing, and pre-production. In France, for example, funding for innovation platforms is provided in response to a call for tenders for structuring projects. However, it is regulated by the European Commission as a non-economic activity.

It should be noted, however, that the sharing of indivisibilities could be subject to negative effects, including congestion caused by saturation of transport routes, overuse of equipment, and lack of energy supply. There may also be competitive effects, especially in the recruitment of researchers, with the risk of hold-ups. Hold-ups generally occur when research investments leave with their beneficiaries, as a result of overbidding on wages and working conditions. According to Crampes and Encaoua (2005), the effects are stronger when inventive activities in the same sector are grouped together (Note 13).

3.4 Localized Technological Cooperation

According to the pioneering work of Lee and Wilde (1979), Loury (1979), and Dasgupta and Stiglitz (1980), the patent race leads to over-investment in R&D and dissipation of the rent from innovation, due to the strategic externalities inherent in competition. Consequently, if firms cooperate and decide to coordinate their levels of investment, they eliminate these externalities and avoid duplication of research efforts. However, the models developed in these pioneering works do not explicitly incorporate the knowledge externalities that are particularly important in innovative industries. Indeed, when part of a firm's research results can be captured by other competing firms, it is expected that firms engaged in non-cooperative R&D will have less incentive to innovate. Consequently, taking account of knowledge externalities in R&D activities makes R&D cooperation an important strategic tool in industrial innovation policies in several developed countries. R&D cooperation is in fact part of the logic of organizing transactions between contractors (Coase, 1937), but also of a strategic logic of complementarity or technological interdependence around innovation activity (Matt, 2000).

One of the most important theoretical contributions to R&D cooperation that takes knowledge externalities into account is that of D'Aspremont and Jacquemin (1988). These authors analyze the effects of R&D cooperation agreements on private incentives to invest, on the quantities of products put on the final market, and on social welfare in the presence of knowledge externalities (Iritié, 2018). Their model considers an industry with two firms i and j that engage in process innovation and produce a homogeneous good on the product market. They must satisfy a total demand $p = a - bQ$ with $Q = q_i + q_j$. Each firm is characterized by a marginal cost of production c_i such as:

$$c_i(x_i, x_j) = A - x_i - \beta x_j; \quad i = 1,2; i \neq j$$

where x_i is a firm i's level of R&D investment and β is the level of knowledge externalities; the parameter β indicates that each firm benefits indirectly from its competitor's research effort. A firm's strategy consists in choosing its level of research effort and the quantity of the good to be put on the market. The model is constructed as a two-stage game, where R&D cooperation precedes the production stage. The results show that, in the presence of a high rate of knowledge externalities ($\beta > 0.5$), firms are better off forming a cooperative structure at the R&D stage than competing. Cooperation not only increases producer profit, but also consumer welfare, and therefore social well-being, provided there is no collusive behavior at the production level. Since the results of D'Aspremont and Jacquemin (1988, 1990) and their numerous extensions in the economic literature (Note 14), R&D cooperation has been considered one of the most widely used methods of coordinating players, and an effective means of stimulating innovation (Note 15).

However, in a recent study, Iritié (2021) developed a model in Industrial Organization that draws broadly on D'Aspremont and Jacquemin's (1988) model, and on Kamien and Zang's (2000) model, to analyze the performance of R&D cooperation agreements within groups of co-localized innovative firms or innovation cluster also assimilated to a localized epistemic community. The question posed by this study is whether R&D cooperation within an innovation cluster is more efficient and preferable individually and socially than R&D cooperation outside the cluster. In other words, does technological cooperation between firms in the same localization have more positive effects on their private incentives to innovate? To this end, Iritié (2021) integrates into his model knowledge externalities and the localized aspect of knowledge externalities, which did not exist in the models of D'Aspremont and Jacquemin (1988) and Kamien and Zang (2000).

The author assumes that two co-localized firms i and j form a research joint venture (RJV). These firms benefit both from knowledge externalities rated β linked to this cooperation agreement and benefit from knowledge externalities rated γ not linked to this RJV agreement but coming from the (n-2) other co-localized firms. The model considers several parameters, such as the absorptive capacity θ of each of the two RJV firms. Note that the absorptive capacity θ_i of firm i is determined by its own research effort x_i and by the cognitive distance δ within the innovation cluster, i.e., $\theta_i \equiv \theta\ (x_i, \delta)$. The value of the cognitive parameter indicates the complexity of the technological knowledge to be assimilated by co-localized firms. It reflects the difficulty of learning. In other words, δ can be equated with the cluster's level of specialization (see Iritié, 2021 for details). Thus, a low rate, $\delta < 0.5$ means that the cluster is formed by an epistemic community with very close and specialized knowledge, while a high rate, $\delta > 0.5$, reflects the opposite.

Based on the proposal by Kamien and Zang (2000), the author proposes a new function for the effective R&D effort or X_i of firm i. This effective R&D effort or X_i considers firm i's own R&D effort, cognitive and absorptive capacity parameters, a fraction of the rival firm's research effort (or intra-RJV knowledge externalities), and a fraction of the R&D effort of other co-located innovative firms (or extra-RJV knowledge externalities). The form of X_i is such that:

$$X_i = x_i + \beta(1-\delta)(x_i)^{\delta}\left(x_j^{1-\delta} + \gamma(\textstyle\sum_3^n \bar{x})^{1-\delta}\right), i = 1,2, i \neq j$$

The two firms *i* and *j* are in a two-stage strategic game in which they decide simultaneously at each stage. In the first stage, the two firms coordinate their investment decisions x_i and x_j within the research joint venture to reduce their marginal production costs given by $c_i(x_i, x_j) = \max(0, A' - X_j)$, $i = 1,2, i \neq j.$ In the second stage, they compete in Cournot fashion to produce quantities $q_i \geq 0$ and $q_j \geq 0$, respectively, of a homogeneous good on the final product market. The total inverse demand is a decreasing function such as $p(Q) = \max(0, a - Q)$ with $Q = q_i + q_j$. The simulation of R&D investment levels in the cooperative equilibrium game in the presence and absence of the innovation cluster shows the importance of technological cooperation agreements within an epistemic community of firms co-localized in the same space. Indeed, the results show that innovation clusters create an informational incentive to innovate within the RJV through the sharing of pre-existing knowledge and the production of new knowledge. Increased local interaction and the knowledge externalities generated by co-localized firms encourage cooperating firms within the duopoly to invest more in R&D. Clusters create a favorable environment (banks, specialized financing, technology platforms, etc.) and improve the performance of technological cooperation. Belonging to a specialized, localized epistemic community therefore strengthens firms' incentives to cooperate in R&D and innovation. Indeed, localization enables a good coupling between research, financing, and the actors in the innovation ecosystem. Social welfare improves, even if this does not totally resolve the classic issue of under-investment in R&D. These results also explain why the co-localization of industries with strong innovation capabilities is observed throughout the world in strategic areas.

4. Conclusion

According to policy, the role of territories is to facilitate the coupling between research, industry, and innovation in order to increase private R&D efforts and industrial competitiveness. In this overview of the literature, we seek to understand the theoretical underpinnings of the concentration of innovation activities around territories. The localization of economic activities is not a new phenomenon, having already been observed in late 19th-century in England. Marshall (1920) explains this organization by the presence of localization externalities supported by the mechanisms of matching, sharing, and learning in a local market. In the 1990s, Krugman provided a theoretical framework for Marshall's intuitions with his "New Economic Geography". It's clear, then, that the general arguments that determine localization are increasing returns and transport costs. However, when it comes specifically to the agglomeration of innovative industries, this can be explained by the presence of knowledge externalities, especially of a tacit nature, the sharing of indivisibilities or technological infrastructures, but also by the gain from R&D cooperation, which becomes more effective within an epistemic community of firms co-localized within an innovation cluster. Indeed, according to Iritié (2021), clusters facilitate the creation of an innovative ecosystem (specialized financing, structuring actors, etc.), encourage R&D cooperation, enable firms to exploit their complementarities, take advantage of knowledge externalities, and minimize the risks associated with innovation. Innovative clusters thus create informational incentives for innovation, through knowledge sharing on the one hand, and the creation of new knowledge on the other.

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Notes

Note 1. The definition of innovation widely used in economics comes from Arrow (1962): an innovation is new information or knowledge.

Note 2. Another theoretical approach to endogenous growth, known as Schumpeterian growth, is put forward by Aghion and Howitt (1992). Here, growth is seen as the result of a process of creative destruction through R&D investment by firms. These models focus on the microeconomic foundations of growth.

Note 3. We distinguish two types of public good: pure public good, i.e., non-rival and non-exclusive (e.g., basic knowledge resulting from fundamental research); and the so-called market public good, i.e., non-rival and exclusive (e.g., knowledge resulting from industrial innovations) (see, Crampes & Encaoua, 2005).

Note 4. Indeed, Solow's neoclassical theory (1956) assumes constant returns to scale; in other words, according to Euler's theorem, paying factors at their marginal productivity exhausts the entire product (see Mas-Colell et al., 1995). If $Y = f(K, L)$ is the level of production and K and L are capital and labor respectively, $Y = \frac{df}{dK} K + \frac{df}{dL} L$, the production is fully distributed between wages and profit. This is impossible in the presence of increasing returns to scale.

Note 5. It's called the dynamic efficiency of imperfect competition and the static efficiency of perfect competition.

Note 6. Schumpeter's prediction of a positive relationship between firm size, market power, and economic progress is justified by the fact that larger, more powerful firms have a greater capacity to appropriate the benefits of innovation, to generate margins to self-finance innovation activity, to bear risks, and to benefit from economies of scale and range effects in the innovation process. Empirical studies such as Acs and Audretsch (1987), Acs and Audretsch (1988a), and Acs and Audretsch (1988b) have analyzed the relationship between firm size and innovation. They show, on the one hand, that large firms have an advantage in terms of innovation and, on the other, that small firms can have an advantage, especially in highly innovative industries.

Note 7. This expression was used by Tirole and Guesnerie (1985) and Tirole (1988) to avoid describing Schumpeter's concept as a "theory".

Note 8. See Tirole and Guesnerie (1985) and Tirole (1988) for complete presentations.

Note 9. The article by Fujita and Thisse (1997) is an excellent review of the theoretical literature on the New Economic Geography.

Note 10. Since Scitovsky (1954), two types of externalities have been distinguished: pecuniary externalities (which refer to the benefits of economic interactions that materialize through the usual market mechanisms, i.e. through price) and technological externalities (which deal with interaction effects that occur outside markets and directly affect consumers' utilities or firms' production functions, and which are accessible to all). Breschi and Lissoni (2001) point out that the boundary between these two types of externalities is blurred. In their view, econometric studies generally underestimate pecuniary externalities and overestimate technological externalities.

Note 11. We speak of centripetal forces for agglomeration and centrifugal forces for dispersion: see Riou (2003) for a detailed presentation of these two forces.

Note 12. The geographic coincidence index C takes the form of a correlation coefficient.

Note 13. In Feldman and Audretsch (1999), Cortright (2006), and Beaudry and Schiffauerova (2009), there is an interesting discussion in the economic literature on the benefits of specialization or diversification of research activities within innovation clusters. For the advocates of specialization, Marshall, Arrow, and Romer, the clustering of innovative industries in the same sector enables the cumulative refinement of knowledge. Advocates of diversification argue that diversity is a source of success, interaction, and the creation of new knowledge and new industries.

Note 14. See, for example, Marjit (1991), Kamien et al (1992), Combs (1992), Motta (1992), Vonortas (1994), De Bondt (1997), Amir and Wooders (1998), Amir (2000), Kamien and Zang (2000) and Miyagiwa and Ohno (2002).

Note 15. For some researchers, the effectiveness of cooperation needs to be put into perspective, as cooperative choices are not always stable. Indeed, Cabon-Dhersin (2007) argues that more than half of all cooperative agreements are doomed to failure while Kogut (1988) showed that 20% of alliances disappear within 5-6 years of their formation. This is because spillovers and incomplete contracts can always give rise to opportunistic behavior, testing the stability of R&D agreements (Boivin & Vencatachellum, 1998; Cabon-Dhersin, 2007). For Kogut (1989), links built on historical experience and exchanges of technological information between two firms foster the stability of R&D cooperation and reciprocity.