WHY ARE TECHNOLOGICAL SPILLOVERS SPATIALLY BOUNDED ? A MARKET ORIENTATED APPROACH

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Cahier N° 02.06.29

Juin 2002

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Why are technological spillovers spatially bounded? A market orientated approach

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January, 2002

Abstract

According to empirical evidence, technological spillovers are spatially bounded. This is one of the main reasons why firms are induced to locate in close prox-imity despite tough competition. This paper is an attempt to endogenize such spillovers. For that purpose, we try to explain why spatial proximity gives more incentives to competing firms to share knowledge. We show that spatial proxim-ity is the best way for firms to prevent free-riding in case of knowledge sharing. Indeed, fiercer competition impedes free-riding provided that such a behavior dampens firms' efficiency and have a dramatic effect on profits. Moreover, our results have important implications for regional policy. We point out that a slight decrease in transport costs triggers spatial polarization which implies knowledge sharing and thereby enhances innovation. A more dramatic decrease in transport costs attains both the objectives of increasing innovation and regional equity.

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+We thank Anne Perrot, Thierry Mayer, Jacques Thisse and two anonymous referres for very helpful comments. We take responsability for any errors.

1 Introduction

The purpose of this paper is to show that market interactions driven by firms' location have a dramatic impact on technological spillovers. Porter (1998) stresses the positive role of spatial proximity:

> "The enduring competitive advantages in a global economy are often heavily local, arising from concentrations of highly specialized skills and knowledge, institutions, rivals related business, and sophisticated customers".

The success of famous clusters specialized in advanced sectors such as the Silicon Valley or Hollywood supports Porter's argument. Nevertheless, the same holds in other countries such as Portugal, France or Italy and in a wide range of industries. One of the main reasons why spatial proximity fosters efficiency is now well established: close geographic proximity fosters knowledge spillovers. Such a stylized fact is largely supported by empirical evidence (Jaffe, Trajtenberg and Henderson, 1993 or Keller, 2000). Moreover, case studies report widespread voluntary exchange of information between firms located in a same region. Indeed, Saxenian (1994) for instance finds examples of collaboration and sharing of information among local producers in the Silicon Valley. A local engineer describes the Wagoon Wheel bar where engineers meet to exchange ideas. Information continues on the job: according to Saxenian, "Competitors consulted one another on technological matters. [...] A variety of more or less formal gatherings, from trade association meetings and trade conferences to trade hobbyists' clubs also served as specialized forums for information exchange". Engineers from different firms used to exchange technological information within working groups set-up by universities such as Berkeley or Stanford located close to most of the firms. It is worth noting that as striking as it appears, knowledge sharing occurs between competing firms. The relatively close proximity makes association easier. Yet, such behaviors are not restricted to advanced sectors. In Northern Italy as well, within industrial districts, geographic proximity enhances trust between competitors and thereby eases cooperation. Pyke, Becattini and Sengenberger (1990) have pointed out that skilled workers exchange ideas within institutions like trade unions, the Church or political parties. All these examples stress the fact that spatial proximity improves non-market relationships that are to a certain extent at the heart of technological spillovers: sharing tacit knowledge implies face-to-face contacts.

As a result, the theoretical literature in Industrial Organization (Belleflamme et al., 2000) highlights that the presence of spatially bounded technological spillovers gives rise to a basic trade off in terms of spatial location: spatial dispersion decreases competition whereas agglomeration fosters technological spillovers. In the same way, Saxenian (1994) stresses the paradox between fierce competition and cooperation in the Silicon Valley. Our main contribution lies in our claim that there is no paradox here. Instead, we argue that fierce competition induced by spatial proximity eases cooperation and exchange of information: competition and cooperation are self-reinforcing. In other terms, we claim that market competition improves non-market relationships such as knowledge sharing or cooperation. Hence our contribution is twofold:

(i) We construct a model emphasizing the basic positive role of competition on technological spillovers. We thus stress that the negative role of distance on spillovers is not only due to exogenous factors but is also linked to the degree of competition on the market. The underlying basic intuition is based on two main arguments.

First, as stressed by a large literature (Tirole, 1988), spatial proximity increases competition between …rms. Indeed, despite a recent dramatic decrease in transport cost, distance still matters (Hanson, 1998): …rms located close to each other face much …ercer competition than if they were located far apart.

Second, we argue that …erce competition gives incentives to share knowledge. We develop a model in which two …rms can innovate if e¤ort is supplied. Nevertheless, a …rm cannot observe the other …rm's e¤ort. As a result, knowledge sharing between both …rms can lead one of them to free-ride. We …rst consider a benchmark in which …rms do not exchange technological information. In that case, each …rm trades-o¤ between the cost of e¤ort and the bene…t of innovation. In contrast, in the case of knowledge sharing, the former trade-o¤ is no longer relevant: a …rm could be induced to free-ride by bene…ting from the knowledge supplied by the other in order to innovate without exerting any e¤ort. Yet„ such a behaviour is likely to deter knowledge sharing since the …rm that exerts e¤ort takes no bene…t to share knowledge. Sharing knowledge can hence be sustained only if …rms must commit not to free-ride. However, free-riding turns out to be pro…table only if the pro…t earned by the free-rider remains high enough, that is if competition remains soft. Consequently, in order to prevent such a behavior, …rms must face tough competition. Close spatial proximity gives rise to such a credible commitment since spatial proximity leads to …ercer competition. As a result, spatial agglomeration is likely to foster knowledge sharing. Yet, we should note that as transport costs su¤er a sharp decrease, competition is likely to become tough between regions. Therefore, according to our prediction, spatial dispersion combined with very low transport costs can lead to exchange of information as well.

(ii) We apply the former framework so as to study …rms' location choice. We establish to what extent locations depend on transport cost in order to discuss the impact of regional policy based on regional integration and transport infrastructure improvement. We claim that high transport costs induce spatial dispersion and therefore low technical progress as …rms do not share knowledge. Intermediate transport costs trigger spatial polarization and favor the exchange of technological information among …rms and thereby spur technical progress. Nevertheless unlike existing models in economic geography (Martin, 1999) this is not the end of the story as low transport costs can lead to spatial dispersion and high technical progress. As a consequence, dramatic regional integration can attain both objectives: foster technical progress and regional equity. The trade o¤ between e¢ ciency and regional equity documented by Quah (1996) among the European Union could eventually be due to lack of regional integration. Stated di¤erently, we argue that …ercer competition between regions is the best way to enhance the development of backward regions. Indeed, again, …ercer competition eases knowledge sharing and di¤usion between …rms even though they locate in di¤erent regions.

The rest of the paper is organized as follows. Section 2 outlines the model. In section 3 we derive equilibrium on the good market. Section 4 analyses the interaction between agglomeration and knowledge sharing. Section 5 discusses the impact of transport cost on firms location and thereby on technical progress, social welfare and regional inequalities.

2 The model

The world consists of two regions, labelled N and S, ex-ante identical. We consider a partial equilibrium model.

To keep matters simple, we consider an industry with two firms labelled firm 1 and firm 2. Each producer faces two types of decisions: production and research.

2.1 The good market

Products are vertically differentiated. The utility of a consumer that buys a product of quality q at price p is

$$U(q,p) = y + q - p$$

where y denotes the income. The income is assumed high enough so that a consumer always buys the good. There is a mass 1 of consumers in each region. Firms compete à la Bertrand, incur transport costs and perfectly discriminate between spatial markets according to empirical evidence (Greenhut, 1981). The unit transport cost is denoted by t. Moreover, production costs are nil. We will regard a decrease in t as an improvement of inter-regional transport infrastructure.

2.2 Research

The quality of firm i depends on the effort (e_i) exerted by researchers within the firm. Indeed, we assume that as effort increases, the researcher increases his stock of knowledge and thereby develops a higher quality. Besides, knowledge developed by a firm has a public good dimension. Spillovers between firms may allow a researcher to benefit from the knowledge developed by the other. Moreover, within firm i, researchers can either exert effort ($e_i = 1$) or not ($e_i = 0$). The cost of exerting effort, $\psi(e)$, satisfies $\psi(1) = \psi > 0$ and $\psi(0) = 0$.

Thus, if x_i denotes the knowledge of firm i, we capture spillovers through the following mechanism:

$$x_i = \begin{cases} x(e_i, e_j) & \text{in presence of spillovers} \\ x(e_i, 0) & \text{in absence of spillovers} \end{cases} \quad (1)$$

Furthermore, function x is specified as follows:

$$x(e_i; e_j) = \begin{cases} q(e_i; e_j) & \text{if the innovation is successful, with probability } p \\ q^b & \text{with probability } 1 - p \end{cases} \tag{2}$$

where $q(.)$ denotes the quality developed by firm i. $q(.)$ takes the following values:

$$q(1;1) = \overline{q} \tag{3}$$
$$q(1;0) = q(0;1) = \underline{q} > q^b \tag{4}$$
$$q(0;0) : \text{No entry} \tag{5}$$

We use the following notation:

$$x(1;1) = \overline{x};\ x(1;0) = \underline{x} \text{ and } x(0;1) = x^{FR} \tag{6}$$

Effort is both a way to enter on the market[1] and to innovate by increasing the quality with probability p. The higher the effort is, the higher the new quality developed is. If both researchers exert effort, positive spillovers effect increases the level of quality. Such positive spillovers are captured by the magnitude of parameter $\overline{q}$. In other words, a researcher that exerts effort develops its own line of research and thereby increases the stock of knowledge.

Nevertheless, when one researcher does not exert effort while the other does so and if spillovers are at work, the former can free-ride and thereby benefits from the effort exerted by the latter. The free-rider innovates and develops the quality $\underline{q}$ whenever the innovation of the other firm is successful. In words, passive spillovers allow a firm to innovate by imitating without incurring the R&D cost Ã.

Furthermore, spillovers are not exogenous. According to Katsoulacos and Ulph (1998), researchers can cooperate and share knowledge only if they design specifically their technologies to do so and decide effectively to share knowledge. We capture through this coordination of research design and knowledge sharing the more or less formal gathering (described in the introduction) firms use in order to exchange information. Therefore, in this model, technological spillovers result from firms' decisions: firms choose to allow or not to allow exchange of information between researchers. Indeed, Saxenian (1994) stresses that firms can decide not to cooperate even though they stay in close spatial proximity. Besides, it is worth noting that expression (1) assumes no exogenous impact of distance on technological spillovers.

One firm does not observe the effort exerted by the other. Therefore, if firms design their technology so as to allow spillovers, they cannot sign a contract contingent to the effort exerted.

[1] This article does not aim at studying the effort incentives within a firm but, instead focuses on the free-rider issue in presence of spillovers. That is the reason why we assume that if there are no spillovers between firms, a firm must exert effort so as to enter the market.

2.3 The game

The sequence of decisions is as follows:

1. Firms choose simultaneously their location.

2. Firms cooperatively agree or disagree to coordinate their technology so as to allow spillovers.

3. Researchers exert effort or do not exert effort.

4. Firms compete on the good market.

Stage 2 captures either the formal formation of a research team or an informal meeting between both firms during which they coordinate their research program in order to be able to share knowledge.

Note that the timing is close to Katsoulacos and Ulph (1998). Yet, here the effort is not observable. This feature may give rise to free-riding.

We solve the game by backward induction. Hence, section 3 sets-up firms' profits while section 4 studies stages 2, 3 and 4. Section 5 is dedicated to the location equilibrium and studies the impact of the transport cost on innovation and welfare.

3 Equilibrium on the good market and profits

In this section we study the equilibrium on the good market so as to derive profits.

Profits will depend on both firms' location. Two configurations may arise: the agglomeration configuration (A) where both firms are located in the same region and the dispersion configuration (D) where firms are not located in the same region.

(I) Firms are agglomerated.

As in Ottaviano et al. (2002), we consider here only configurations in which firms have always access to the foreign market: the transport cost is lower than the lowest quality, that is:

$$t < q^b \tag{7}$$

Therefore, on the market where firms are located (the home market) as well as on the foreign market, Bertrand competition leads to the following profit for firm i:

$$Max(q_i - q_j; 0) \tag{8}$$

Hence, the profit of firm i that exerts effort e_i in configuration A denoted by $\pi^A(x(e_i; e_j); x((e_i; e_j); t)$ is equal to:

- In the absence of free-riding:

$$\pi^A(x(e_i; e_j); x((e_i; e_j); t) = p(1 - p)2(q(e_i; e_j) - q^b) \tag{9}$$

- In the presence of free-riding:

$$\pi^A(\underline{x}; x^{FR}; t) = \pi^A(x^{FR}; \underline{x}; t) = 0 \tag{10}$$

- Moreover, by assumption:

$$\pi^A(x(0;0); x(\cdot;\cdot)) = 0 \tag{11}$$

(II) Firms are spatially dispersed

In order to clarify the exposition, assume that firm i is located in region S:

- In region S; (the home market of firm i), Bertrand competition leads to the following profit for firm i :

$$Max(q_i - q_j + t; 0) \tag{12}$$

and firm j makes a profit equal to

$$Max(q_j - q_i - t; 0) \tag{13}$$

As in standard spatial models, spatial dispersion softens competition: the transport cost incurred by firm j increases the mark-up of firm i on its home market.

- In region N (the foreign market of firm i); firm i enjoys the following profit:

$$q_i - q_j - t \text{ if } t < q_i - q_j \tag{14}$$

$$0 \text{ if } t > q_i - q_j \tag{15}$$

This is the symmetric of the former configuration: on the foreign market, a firm incurs a transport cost. Thus, if the quality gap, $q_i - q_j$; is not high enough compared to the transport cost, the firm makes no profit.

Hence, firm j enjoys a profit equal to:

$$0 \text{ if } t < q_i - q_j \tag{16}$$

$$\text{and } q_j - q_i + t \text{ if } t > q_i - q_j \tag{17}$$

Therefore, the profit of firm i is given by the following expressions:

- In the absence of free-riding:

$$\pi^D(x(e_i; e_j); x((e_i; e_j); t)) \tag{18}$$

$$= \begin{cases} p(1-p)2(q(e_i;e_j) - q^b) + [p^2 + (1-p)^2]t \text{ if } t < q(e_i;e_j) - q^b \\ [p^2 + (1-p)^2]t + p(1-p)(2t) = t \text{ if } t > q(e_i;e_j) - q^b \end{cases} \tag{19, 20}$$

- In the presence of free-riding:

$$\pi^D(\underline{x}; x^{FR}; t) = \pi^D(x^{FR}; \underline{x}; t) = t \tag{21}$$

- By assumption:

$$\pi^D(x(0;0); x(\cdot;\cdot)) = 0 \tag{22}$$

Comparison of profits in the agglomerated configuration and in the dispersed configuration leads to the following lemma.

Lemma 1 For any value of t; we have $\pi^A(x;x;t) \geq \pi^D(x;x;t)$

As in standard spatial models, spatial dispersion weakens competition. Therefore competition plays a centrifugal role: two identical …rms choose to locate in di¤erent regions. Obviously, this result is not surprising and allows to focus on the centripetal force.

4 Location and spillovers

Preceding section determined …rms' pro…ts and stressed to what extent they depend on both …rms' location and qualities. The next step turns to study …rms' strategies in terms of research activity for given locations. In particular, we have to determine whether …rms agree to allow spillovers by sharing knowledge.

Figure 1 represents the subgame that follows the location stage (stage 1).

…gure 1

We …rst study the case where …rms at stage 2 disagree and do not coordinate their research design. This subgame can be considered as the benchmark since it stresses what happens in case of disagreement.

(I) No coordination of technology design (absence of spillovers)

The e¤ort exerted by a …rm depends on the belief on the e¤ort exerted by the competitor. We focus on pure strategies Perfect Bayesian Equilibria. Consider …rm 1. Two cases may arise according to either the …rm beliefs the other exerts e¤ort ($\gamma_2 = 1$) or it beliefs the opposite ($\gamma_2 = 0$).

(i) Firm 1 beliefs that …rm 2 exerts e¤ort ($\gamma_2 = 1$).

The best response is $e_1 = 1$ if

$$\pi(\underline{x};\underline{x};t) - \chi > \pi(0;\underline{x};t) = 0 \quad (23)$$

$$\text{iff } \chi < \pi(\underline{x};\underline{x};t) = \underline{\chi} \quad (24)$$

In words, …rm 1 exerts e¤ort if the duopoly pro…t ($\pi(\underline{x};\underline{x};t)$) does not exceed the cost of e¤ort.

(ii) Firm 1 beliefs that …rm 2 does not exert e¤ort ($\gamma_2 = 0$):

It will always exert e¤ort ($e_1 = 1$) if

$$\pi(\underline{x};0;t) - \chi > \pi(0;0;t) = 0 \quad (25)$$

$$\text{iff } \chi < \pi(\underline{x};0;t) = \overline{\chi} \quad (26)$$

As before, e¤ort is exerted if the monopoly pro…t, $\pi(\underline{x};0;t)$; exceeds the cost.

Therefore[2], there are three possible equilibria in the subgame that follows the no coordination on research design:

[2] We deduce by symmetry the optimal strategy of …rm 2.

(a) $\tilde{A} < \underline{\tilde{A}}$: The cost is low and both …rms exert e¤ort.

(b) $\underline{\tilde{A}} < \tilde{A} < \overline{\tilde{A}}$: The cost is neither high nor low so that only one …rm exerts e¤ort and the other stays outside the market.

(c) $\tilde{A} > \overline{\tilde{A}}$ The cost is so high that entry is not pro…table and therefore neither …rm exerts e¤ort.

We assume that in the absence of spillovers entry is always pro…table for both …rms: the cost $\tilde{A}$ is low enough so that a duopoly is viable. Thereafter, it is assumed that $\tilde{A} < \underline{\tilde{A}}$: In our speci…cation, the assumption is equivalent to $\tilde{A} < 2p(1 ¡ p)(\underline{q} ¡ q^b)$:

(II) Coordination of research design (presence of spillovers)

In that case, …rms share knowledge.

As before, we focus on pure strategies equilibria. At stage 3, each …rm chooses its level of e¤ort. As before, three possible equilibria may arise.

(a) Both …rms exert e¤ort ($¯_1 = ¯_2 = 1$).

It is an equilibrium if a …rm has incentives to exert e¤ort ; that is if:

$$¼(\overline{x}; \overline{x}; t) ¡ \tilde{A} > ¼(x^{FR}; \underline{x}; t) \quad (27)$$

This condition is straightforward. On the one hand, since …rms share knowledge, a …rm can enjoy pro…t $¼(x^{FR}; \underline{x}; t)$ at no cost thanks to passive spillovers. On the other hand, because of active spillovers, exerting e¤ort at cost $\tilde{A}$ gives a pro…t $¼(\overline{x}; \overline{x}; t)$: As a result, the …rm exerts e¤ort if the opportunity cost $\tilde{A} + ¼(x^{FR}; \underline{x}; t)$ does not exceed the bene…t measured by $¼(\overline{x}; \overline{x}; t)$: In other words, net bene…t must exceed the direct cost:

$$\tilde{A} < ¼(\overline{x}; \overline{x}; t) ¡ ¼(x^{FR}; \underline{x}; t) = \hat{\tilde{A}} \quad (28)$$

While active spillovers increase the incentives to exert e¤ort, passive spillovers increase the opportunity cost of exerting e¤ort and thus induce a …rm to free-ride.

(b) One …rm does not exert e¤ort ($¯_1 = 0; ¯_2 = 1$)

It is an equilibrium if …rm 1 has no incentives to exert e¤ort and …rm 2 is not induced not to exert e¤ort ; that is if

$$\tilde{A} > \hat{\tilde{A}} \quad (29)$$

$$\text{and } ¼(\underline{x}; x^{FR}; t) ¡ \tilde{A} > 0 \quad (30)$$

(c) Firms do not exert e¤ort ($¯_1 = 0; ¯_2 = 0$)

It is an equilibrium if no …rm is induced to exert e¤ort ; that is if:

$$¼(\underline{x}; x^{FR}; t) ¡ \tilde{A} < 0 \quad (31)$$

In brief, if …rms decide to coordinate their research design and thereby enhance spillovers, two equilibria are in order:

First equilibrium: if $\tilde{A} < \hat{\tilde{A}}$; both …rms exert e¤ort and share knowledge.

Therefore, in that case …rms cooperatively decide to coordinate their research design since the pro…t enjoyed is $¼(\overline{x}; \overline{x}; t) ¡ \tilde{A}$ rather than $¼(\underline{x}; \underline{x}; t) ¡ \tilde{A}$:

Indeed, if the cost of effort is low ($\psi < \hat{\psi}$), sharing knowledge does not induce free-riding so that both firms have incentives to exert effort. Therefore, because of active spillovers firms are induced to coordinate their research design in order to allow such spillovers and thereby to benefit from a higher stock of knowledge. Eventually, active spillovers are at work.

Second equilibrium: if $\psi > \hat{\psi}$; either both firms do not exert effort or one of them exerts effort while the second free-rides[3].

Consider first the case where one firm exerts effort. If firms coordinate their research design and share knowledge, the firm that does not supply effort enjoys

$$\pi(x^{FR}; \underline{x}; t) \tag{32}$$

while the other one enjoys

$$\pi(\underline{x}; x^{FR}; t) - \psi \tag{33}$$

If the firm that exerts effort refuses to share knowledge, its profit becomes

$$\pi(\underline{x}; \underline{x}; t) - \psi \tag{34}$$

which is higher than $\pi(\underline{x}; x^{FR}; t) - \psi$.

In words, if one firm does not exert effort, the other is reluctant to give knowledge to a free-rider.

Eventually, in the case where both firms do not exert effort, each one enjoys 0 and thus is induced not to share knowledge.

Hence, if ψ is higher than $\hat{\psi}$, firms have no interest to coordinate their research design and the profit enjoyed is equal to $\pi(\underline{x}; \underline{x}; t) - \psi$.

Moreover, we should note that whenever $\underline{\psi}$ remains higher than $\hat{\psi}$, assuming that ψ is lower than $\underline{\psi}$ has no impact on the equilibrium. Indeed, for high values of ψ, only one firm enters on the market without accepting to share knowledge because ψ is so high that the other firm will free-ride.

In brief, firms accept to foster spillovers only if confidence is such that each one knows that the other has no incentives to free-ride. The following lemma gives the equilibrium of the subgame that follows the location stage.

Lemma 2 Firms agree to allow spillovers by both coordination of research design and knowledge sharing if and only if

$$\psi < \pi(\bar{x}; \bar{x}; t) - \pi(\underline{x}; x^{FR}; t) = \Delta\pi(\bar{x}; t) = \hat{\psi} \tag{35}$$

This inequality is equivalent to $\bar{q} > \phi(\underline{q}; \psi; t)$.

[3] We assume here that $\hat{\psi} < \underline{\psi} = \pi(\underline{x}; \underline{x}; t)$. This is always the case for $\underline{x}$ high enough since $\pi(x^{FR}; \underline{x}; t)$ does not increase with $\underline{x}$.

Proof

Whatever the location configuration, expression $\pi(\overline{x};\overline{x};t) - \pi(\underline{x};x^{FR};t)$ increases with $\overline{q}$: Moreover, if $\overline{q} = \underline{q}$; $\pi(\overline{x};\overline{x};t) - \pi(\underline{x};x^{FR};t) < 0$ and if $\overline{q}$ goes to infinity, $\pi(\overline{x};\overline{x};t) - \pi(\underline{x};x^{FR};t)$ goes to infinity as well. Moreover, firms coordinate their research design and share knowledge iff $\pi(\overline{x};\overline{x};t) - \pi(\underline{x};x^{FR};t) > \psi$: ■

So as to share knowledge, firms must commit to exert effort. It is the case if the direct cost is low compared to the net benefit. That may occur if the profit gap, $\pi(\overline{x};\overline{x};t) - \pi(\underline{x};x^{FR};t)$; results high enough.

Everything that widens the profit gap will encourage spillovers. The gap depends on technological parameters that influence the level of passive spillovers, $\underline{q}$; as well as the level of active spillovers, $\overline{q}$. Thus, high active spillovers or low passive spillovers spur the incentives to share knowledge.

Nevertheless, competition on the market modifies the magnitude of this gap as well. Indeed, we expect that tough competition is much more harmful to a free-rider than soft competition. Let us examine in details the profit gap ** according to the level of competition, that is according to firms' location.

Whenever firms are agglomerated the profit gap is equal to:

$$\Delta\pi^A(\overline{x};t) = 2p(1-p)(\overline{q}-q^b) \tag{36}$$

Instead, whenever firms are dispersed, the gap depends on the level of transport cost:

$$\Delta\pi^D(\overline{x};t) = \begin{cases} 0 \text{ if } t > \overline{q}-q^b \\ 2p(1-p)(\overline{q}-q^b-t) \text{ if } t < \overline{q}-q^b \end{cases} \tag{37}$$

As a result, we can state the following result:

Lemma 3 We have always $\Delta\pi^A(\overline{x};t) > \Delta\pi^D(\overline{x};t)$

Proof

>From expressions 36 and 37, we have:

$$\Delta\pi^A(\overline{x};t) - \Delta\pi^D(\overline{x};t) = \begin{cases} 2p(1-p)(\overline{q}-q^b) \text{ if } t < \overline{q}-q^b \\ 2p(1-p)t \text{ if } t > \overline{q}-q^b \end{cases} \tag{38}$$

■

We are now ready to address our main question: whether firms' location is likely to modify the incentives to encourage spillovers by sharing information? The lemma 3 states that agglomeration magnifies the profit gap, that is the net benefit of exerting effort in case of spillovers, and thereby gives firms higher incentives not to free-ride than dispersion.

The basic intuition underlying this result is the following. When both firms are agglomerated, exerting effort is a way to escape from tough competition: if a firm innovates, it sells a better good that its competitor. Additionally, if a firm free-rides, tough competition reduces profits to zero. Rather, when firms are dispersed, transport costs soften competition and thereby increase the profit in case of free-riding. As a result, dispersion and soft competition gives incentives to free-ride.

We can summarize this result in the following proposition.

Proposition 1 Spatial agglomeration fosters the exchange of technological information among competitors since geographic proximity induces tough competition and thereby deters free-riding ($\hat{t}^A \geq \hat{t}^D(t)$).

Proof

(i) $\hat{t}^A$ is such that $\Delta\pi^A = 2p(1-p)(\hat{t}^A - q^b) = \chi$. Because $2p(1-p)(\overline{q} - q^b) > 2p(1-p)(\underline{q} - q^b) > \underline{\chi}$, we have $\hat{t}^A < \underline{q}$.

(ii) $\hat{t}^D$ is such that $\Delta\pi^D = \chi = \begin{cases} 0 & \text{if } t > \overline{q} - q^b \\ 2p(1-p)(\overline{q} - q^b - t) & \text{if } t < \overline{q} - q^b \end{cases}$

If $t < \overline{q} - q^b$, $\hat{t}^D(t) = t + q^b + \frac{\chi}{2p(1-p)}$ or $\hat{t}(\overline{q}) = \overline{q} - q^b - \frac{\chi}{2p(1-p)}$

Note that $\overline{q} - q^b - \frac{\chi}{2p(1-p)}$ is always lower than $\overline{q} - q^b$.

Note that for $\underline{q}$ high enough, we have always $\hat{\chi} < \underline{\chi}$ ■

Empirical evidence supports such a stylized fact according to which knowledge spillovers are spatially restricted. Jaffe, Trajtenberg and Henderson (1993) present the best evidence showing that a new patent is much more likely to cite a patent that is close spatially, even controlling for firm effect. Ciccone and Hall (1996) also show a positive correlation between density and productivity at the state level in the United States.

In contrast with existing models, the explanation we bring here does not rely on knowledge transmission costs from one region to another. Instead, we show that spatial proximity induces firms to voluntarily share knowledge in a world where there is no exogenous cost to transmit technological information from one region to another. The underlying reason why firms adopt such a strategy is the following. Knowledge sharing is a source of efficiency since firms can produce higher qualities. Nevertheless, if firms decide to share knowledge, one of them could be led to adopt a free-riding behavior. Indeed, a firm can be induced to benefit from the knowledge of the other without exerting effort. Competition is a way to avoid such a behavior provided that on a highly competitive market, the profit earned by the free-rider is low. So, as spatial proximity induces tough competition between firms, it spurs knowledge sharing between firms. In contrast, spatial dispersion weakens competition and thereby implies free riding and therefore deters cooperation and knowledge sharing.

Furthermore, our results are close to Aghion, Rey and Dewatripont (1999) or Schmidt (1997) where researchers are induced to exert effort in the presence of tough competition so as to avoid failure.

Here, spatial agglomeration is as a commitment on firms' behavior and thereby a source of confidence between firms. This confidence leads to cooperation and knowledge sharing. Hence, paradoxically, firms are induced to look for tough competition so as to foster spillovers and increase their quality. This result is in sharp contrast with the literature on endogenous spillovers and the formation of joint-ventures (Katz and Ordover, 1990 or Katsoulacos and Ulph, 1998) according to which firms are more likely to form a joint venture in case of soft competition. Nevertheless, both papers do not tackle with free-riding issues within a joint venture.

Finally, note that low transport costs enhance competition between regions and could lead to such a confidence, including between firms spatially dispersed. Such a result holds whenever distance has little damage on technological spillovers, captured in the model by the parameter $\overline{q}$; that does not depend on firms' location. Yet, according to Baldwin and Martin (1999), the second globalization wave initiated in the 1990s is characterized by a dramatic decrease in such communication costs.

Remark 1 We can argue that competition on the product market is driven by other features than firms' location. In that case, the model remains relevant and gives insights into the relationships between location and knowledge sharing. Indeed, we can interpret the model as follows. Both spatial markets correspond to two different goods, each firm is characterized by a basic technology with which it can produce one good at no cost so that parameter t is the unit cost a firm must incur in order to produce the other good. In that framework, t measures the degree of competition between both firms. Moreover, the economy is spatially integrated: there is no transport cost between both regions. Thus, profits are always given by the expression $\pi^D(.)$: Eventually, we assume that firms must locate in the same region so as to share knowledge because such cooperation needs face-to-face contacts.

In that context, the previous result (proposition 1) can be stated as follows: firms locate in the same region (at stage 1) in order to share knowledge if competition on the good market is high enough compared to technological spillovers ($\overline{q} > \phi(\underline{q}; \psi; t)$).

Next section turns to study location equilibrium.

5 Location, transport cost and innovation

The previous section determines the impact of firms' location on spillovers. Thus, this section first provides location equilibrium and second studies the impact of the transport cost on innovation and welfare.

5.1 Location equilibrium

The role of location on spillovers is affected by the level of the transport cost as well as by the level of active spillovers.

(I) First, consider low research spillovers ($\overline{q} < \phi^D(t)$) so that spillovers arise only in the agglomerated configuration. Hence, the location choice gives rise to the following trade-off between an agglomeration force and a dispersion force. On the one hand, spatial agglomeration is the only way to encourage spillovers. The induced technical progress benefit increases with $\overline{q}$: indeed, profit $\pi^A(\overline{x}; \overline{x}; t)$ raises as the level of quality $\overline{q}$ gets higher: On the other hand, spatial dispersion implies less competition between firms: profit $\pi^D(\underline{x}; \underline{x}; t)$ increases whenever the transport cost increases. This competition effect increases with the transport cost, t: In other words, the magnitude of the agglomeration force depends on $\overline{q}$ whereas the magnitude of the dispersion force is driven by the transport cost t: therefore, ceteris paribus, an increase in $\overline{q}$ or a decrease in the transport cost favor spatial agglomeration.

Formally, firms' agglomeration is an equilibrium whenever:

$$\pi^A(\overline{x}; \overline{x}; t) - \pi^D(\underline{x}; \underline{x}; t) > 0 \quad (39)$$
$$\text{iff } \overline{q} > \widehat{q}(t) \quad (40)$$

The threshold $\widehat{q}(t)$ increases with t: a decrease in transport cost strengthens the tendency toward agglomeration provided that a decrease in transport cost strengthens competition in the dispersed configuration. This threshold can be inverted ($\widehat{t}(q)$) and gives the level of transport cost below which a firm enjoys higher profit in the agglomerated configuration than in the dispersed configuration.

We prove in the appendix that $\widehat{q}(t) < \widetilde{q}^D(t)$ whenever the transport cost is low enough ($t < \overline{t}$):

(II) Second, consider high research spillovers ($\overline{q} > \widetilde{q}^D(t)$) so that firms allow spillovers even though they are dispersed. In that case, firms locate in two different regions so as to reduce competition: there is no agglomeration force whereas competition remains a dispersion force.

Crossing the two preceding boundaries allows to determine the location equilibrium.

Insert figure 2

Three different regimes may arise according to values of $(\overline{q}; t)$:

1. Regime DN: Firms are spatially dispersed (D) and do not share knowledge (N): Thus qualities are low. This regime holds for low research spillovers ($\overline{q} < Min(\widetilde{q}^D(t); \widehat{q}(t))$ or whenever transport costs are high ($t > Max(\widehat{t}(\overline{q}); \widetilde{t}(\overline{q}))$). Indeed, high transport costs combined with low research spillovers prevent firms from agglomerating in the same region in order to encourage spillovers: the dispersion force offsets the agglomeration force.

2. Regime AS: Firms are spatially agglomerated (A) and allow spillovers (S): Qualities are high. This regime holds whenever research spillovers are intermediate ($\widehat{q}(t) < \overline{q} < \widetilde{q}^D(t)$) and the transport cost is intermediate ($\widehat{t}(\overline{q}) > t > \widetilde{t}(\overline{q})$): The intermediate level of both research spillovers and transport costs leads firms to locate in close proximity in order to benefit from technological spillovers. Here the agglomeration force driven by the level of research spillovers dominates.

3. Regime DS: Firms are spatially dispersed (D) and allow spillovers (S): Qualities are high: This regime holds whenever research spillovers are high ($\overline{q} > Max(\widetilde{q}^D(t); \widehat{q}(t))$ and the transport cost is low ($t < Min(\widehat{t}(\overline{q}); \widetilde{t}(\overline{q}))$). Fierce competition due to low transport costs and high research spillovers induce firms to foster spillovers even located in different regions.

We assume by convention that …rms cluster in region North (N).

The transport cost level as well as the magnitude of research spillovers determine to a certain extent which regime prevails. Thus, a decrease in transport cost has a direct impact on location and therefore an indirect e¤ect on spillovers and eventually on welfare. The next two sub-sections aim at studying these transport cost e¤ects.

5.2 Transport cost, location and innovation

We discuss the impact of a decrease in transport cost on …rms' location as well as on innovation. As illustrated by …gure 2, the impact of transport cost depends on the level of research spillovers.

(a) First we focus on low research spillovers ($\bar{q} < \varphi^D(\bar{t})$): If transport costs are very high ($t > \varphi(\bar{q})$), soft competition deters …rms to enhance spillovers and lead them to locate in di¤erent regions. A slight decrease in transport cost increases competition and thereby induces …rms to share knowledge even dispersed: the economy switches from regime DN to regime DS: Such a decrease enhances spillovers without a¤ecting …rms' location.

(b) Second, consider the case of intermediate research spillovers ($\varphi^D(\bar{t}) < \bar{q} < \varphi^D(t = q^b)$). In that case, very high transport costs deter spatial agglomeration through the competition e¤ect. Moreover, research spillovers are not high enough to deter free-riding. A decrease in transport costs weakens the competition e¤ect and thereby triggers spatial agglomeration since …rms can enhance spillovers: the economy switches from regime DN to regime AS: In words, a slight decrease in transport cost triggers spatial agglomeration and spurs innovation. Nevertheless, a more dramatic fall in transport cost leads to tough inter-regional competition and therefore induces …rms to encourage spillovers even though they are located in di¤erent regions: the economy switches to regime DS: Such a dramatic decrease in transport cost favors both spatial dispersion and innovation.

(c) Let turn to high research spillovers ($\bar{q} > \varphi^D(t = q^b)$). High research spillovers lead …rms to foster spillovers whatever their location. The transport cost has no e¤ect neither on …rms' location nor on spillovers: the economy stays in regime DS:

The following proposition summarizes the impact of transport cost on the economy.

Proposition 2 *If we focus on intermediate research spillovers, (i) a slight decrease in transport costs triggers spatial agglomeration and spurs innovation, while (ii) a dramatic decrease in transport cost triggers spatial dispersion and spurs innovation.*

The …rst point is in line with European empirical evidence (Quah (1996)) and highlights the connection between spatial agglomeration and economic growth. The explanation we bring here is the following. Spatial agglomeration eases knowledge sharing between …rms and thereby spurs technical progress and economic growth. Moreover, a decrease in transport cost favors such spatial agglomeration by boosting competition if …rms stay spatially dispersed.

Nevertheless, the second point stresses that if the transport cost is low enough, spatial dispersion is consistent with high economic growth. Indeed, low transport costs boost inter-regional competition and thereby can eventually induce knowledge sharing even if firms stay located in different regions. This result is in sharp contrast with standard economic geography models in which economic growth is spurred only by firms' agglomeration (see for instance Baldwin et al. (2001)). Indeed, technological spillovers are assumed spatially restricted. Instead, in this model, as knowledge sharing is endogenous, we explain to what extent distance impedes such technological spillovers.

Note that a transport cost fall can spur innovation to the detriment of regional equity: the South may be negatively affected by firms' polarization. Therefore we need to study the impact of a decrease in transport cost on social welfare.

5.3 Transport cost, welfare and regional inequalities

We note W the social welfare in the whole economy. It is defined as the sum of profits and consumers surplus. Hence W depends on the regime prevailing in the economy:

(1) If regime DN prevails, global welfare is:

$$W^{DN}(t;\underline{q}) = \begin{cases} 2\left(p\underline{q} + (1-p)q^b\right) - 2\psi & \text{if } t > \underline{q} - q^b \\ 2(1-(1-p)^2)\underline{q} + (1-p)^2 2q^b - 2p(1-p)t - 2\psi & \text{if } t < \underline{q} - q^b \end{cases} \tag{41}$$

If the transport cost is high, both regions do not trade whereas if the transport cost is low, because of increasing competition between firms, both regions enjoy the highest quality. The highest quality is equal to $\underline{q}$ since firms do not share knowledge.

(2) If regime AS prevails, global welfare is:

$$W^{AS}(t;\overline{q}) = 2(1-(1-p)^2)\overline{q} + (1-p)^2 2q^b - t - 2\psi \tag{42}$$

If one firm innovates, both regions enjoy the highest quality because of tough competition between firms. The highest quality is equal to $\overline{q}$ since firms share knowledge. Nevertheless, goods must be always shipped from one region to another at total cost t.

(3) If regime DS prevails, global welfare is:

$$W^{DS}(t;\overline{q}) = 2(1-(1-p)^2)\overline{q} + (1-p)^2 2q^b - 2p(1-p)t - 2\psi \tag{43}$$

This case is the symmetric of case DN with quality $\overline{q}$ instead of $\underline{q}$: This is the most efficient configuration since spatial dispersion minimizes total transport costs and firms foster spillovers.

Eventually, a decrease in transport cost has three different effects on the economy: a transport cost effect, a location effect and an innovation effect:

- The transport cost effect: a decrease in transport cost reduces total transport costs (for given locations).

- The location effect: a decrease in transport cost is likely to modify firms' location and therefore modifies the degree of competition as well as total transport costs incurred by the economy.

- The innovation effect: in the same way, a decrease in the level of transport cost is likely to lead the economy from a regime without spillovers to a regime with spillovers.

The global impact of the transport cost on the economy depends on the level of research spillovers.

(a) For intermediate research spillovers ($\phi(\bar{t}) < \bar{q} < \phi(t = q^b)$), a slight decrease in transport cost moves the economy from regime DN to regime AS (see figure 2): The welfare comparison is the following:

$$W^{AS} > W^{DN} \tag{44}$$

$$\text{iff} \quad p(\bar{q} - \underline{q}) + p(1 - p)(\bar{q} - q^b) > t \tag{45}$$

Such a decrease has a positive innovation effect, a location effect and a positive transport cost effect. First, consider a slight decrease in transport cost in the neighborhood of the border between both regimes (the threshold $t = \theta(\bar{q})$). Such a decrease has two effects[4]:

- The innovation effect: agglomeration fosters spillovers and gives rise to an increase of quality equal to $(\bar{q} - \underline{q})$:

- The location effect: agglomeration of firms in one region improves competition and thereby leads both regions to enjoy the highest quality. Yet, agglomeration increases total transport costs incurred by the economy.

Thus, the effect of the slight decrease in transport cost is ambiguous. Yet, around the threshold $\theta(\bar{q})$, firms are indifferent between both locations so that profits $\pi^A(\bar{x}; \bar{x}; t)$ and $\pi^D(\underline{x}; \underline{x}; t)$ are equal, that is:

$$p(1 - p)(\bar{q} - q^b) = t \tag{46}$$

We deduce that the economy is better off is the regime AS than in the regime DN:

$$W^{AS}(t = \theta(\bar{q})) > W^{DN}(t = \theta(\bar{q})) \tag{47}$$

The reason is three-fold. First, since firms incur transport costs, they perfectly internalize the transport cost effect. Moreover, because of the inelastic demand function, firms capture the consumer surplus and internalize the innovation effect. Nevertheless, they ignore the positive effect of agglomeration on competition.

Hence a slight decrease in transport cost around the threshold gives rise to a net increase in global welfare.

As a result the economy suffers from too less agglomeration. In brief, spatial agglomeration is beneficial thanks to its positive impact on innovation. Nevertheless such an impact occurs at the expense of region South. Yet, a dramatic transport cost decrease leads the economy from regime AS to regime DS: Such a decrease has a positive location and transport cost effects and is beneficial to region South.

(b) In case of low research spillovers, a decrease in transport cost can move the economy from regime DN to regime DS: Such a decrease has a positive innovation effect and a positive transport cost effect: it improves welfare.

The following proposition summarizes the impact of the transport cost on welfare.

[4] here by construction, the transport cost effect is nil.

Proposition 3 A slight decrease in transport costs bene…ts the whole economy to the detriment of regional equity. Nevertheless a dramatic decrease in transport costs attains both objectives of higher welfare and regional equity.

As in Baldwin, Martin and Ottaviano (2001), a decrease in transport cost gives rise to a sort of "Kuznets curve" relation between transport cost and regional inequalities : indeed, if the economy starts from high transport costs, a decrease induces more regional inequalities. In contrast, in later stages of regional integration, if transport costs are lower, a decrease in transport cost reduces inequalities between regions. Nevertheless, here, in contrast to Baldwin et al. (2001) the South bene…ts from re-industrialization as a …rm eventually chooses to locate in the South. As a consequence regional inequalities disappears as transport cost becomes low enough. Instead, in Baldwin et al. (2001) even though regional inequalities decrease with transport cost, the South stay under-industrialized. Our result is in line with Krugman and Venables (1995) or Puga (1999) where if regional integration go far enough it can bring regional re-industrialization.

As a result, our main economic policy lesson could be stated as follows. Any regional policy that aims at protecting the South from competition does induce spatial dispersion of …rms but it does so at the expense of global e¢ciency. According to our prediction, …rms are induced to cluster in the North because competition eases knowledge sharing. Hence, a policy that fosters inter-regional competition by improving inter-regional transport infrastructure can induce eventually spatial dispersion of …rms combined with knowledge sharing. It is worth noting that the present reform of the European Union regional funds Interreg promotes cooperation projects between developed regions and less developed regions rather than between less developed regions only.

6 Concluding remarks

The present paper is an attempt to explain the impact of both market competition and …rms' location on the incentives to foster technological spillovers. We stress that because spatial proximity implies tough competition, …rms are keen to share knowledge. Indeed, …rms are reluctant to share knowledge since they fear free-riding. Nevertheless, competition impedes such a free-riding. In other words, local competition gives rise to technological spillovers and thereby to knowledge sharing.

The empirical relevance of such a model would depend on the correlation between local technological spillovers and regional competition. We would expect that regions a¤ected by tough competition also experiment widespread technological spillovers.

Moreover, as far as the location choice is concerned, …rms can locate in the same region and face more competition in order to share technological information. Yet, we show that as a dramatic decrease in transport leads to tough competition including between regions, such a decrease could induce knowledge sharing even though …rms remain spatially dispersed. Therefore, in contrast with standard economy geography literature, a dramatic decrease in transport cost leads to both higher technical progress and …rms' spatial dispersion. In other terms, a transport infrastructure improvement conciliates regional equity and global e¢ciency.

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7 Appendix

Intersection of $\mathbf{b}(t)$ and $\mathbf{e}^D(t)$:

Both curves intersect in $t = \bar{t} = \frac{2p(1-p)}{2p-1}(\underline{q} - q^b) - \frac{\psi}{2p-1}$. We can always find values of p and ψ such that this value is lower than q^b for any $\underline{q}$.