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Information asymmetry as a source of spatial agglomeration

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Abstract

This article interprets spatial location as a way for firms to signal innovation. In the model, spatial agglomeration is due to information asymmetry. Moreover, a decrease in inter-regional transport costs has a strong impact on industry and favors agglomeration.

Keywords: Location; Signaling; Quality

JEL classification: L15; R30

1. Introduction

Famous luxury firms are all located in west downtown Paris. Despite competition, firms specializing in 'haute couture', jewelry or leather are clustered in places such as Avenue Montaigne or Place Vendôme. In northern Italy, industrial districts in sectors such as ceramics, ready to wear or toys are numerous.

The 'New Economic Geography' literature (see Fujita and Thisse, 1996, for a survey) usually identifies three main reasons as to why firms cluster: lower transportation cost in the presence of increasing returns, better matching on the labor market, and localized technological externalities.

This article shows that information asymmetries can also be a source of agglomeration. We argue that firms use location as a signal of product quality. Indeed, only a firm that innovates in a better quality product can endure competition induced by proximity to existing firms. Hence consumers anticipate that high-quality firms are the only ones to locate in clusters. This result fits well with the facts: in an empirical study (Audretsch and Feldman, 1999), localized competition is found to be an attracting force for new firms.

This article also shows that a decrease in transportation costs can have a dramatic effect on

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location: it can induce a lock-in of innovative firms' location in one region and thereby lead to regional inequalities.

Section 2 describes the model. Firms' location in symmetric information is studied as a benchmark in Section 3. We examine location under asymmetric information in Section 4.

2. The model

We consider two regions: North (N) and South (S). The number of agents in each region is normalized to 1. Agents have identical preferences:

$$U(q,P)=\begin{cases} q-P, & \text{if } q-P\geq 0,\\ 0, & \text{otherwise,}\end{cases} \tag{1}$$

where P is the price of one unit of a good of quality q.

We denote λ the unit transportation cost required to carry goods from one region to another. Firms are assumed to adopt a delivered pricing policy (they incur the transportation costs) and are allowed to price discriminate between markets. Firms incur no production costs.

An incumbent (firm I) produces the current quality, q^{I} ($q^{\mathrm{I}}>\lambda$)[1], which is commonly known. We assume without loss of generality that I is located in the North. The exogenous quality product of the new entrant (firm E) is $q=q^{\mathrm{I}}+\gamma$. The 'innovation' size γ is distributed on $[0,\bar{\gamma}]$ according to density f. Let γ^{m} be the mean of the innovation size. The quality of firm E will be revealed through consumption. Consumers know f.

3. Location with symmetric information

The game proceeds in three stages.

- Stage 1. The new entrant, E, chooses its location: $l\in\{\mathrm{N,S}\}$. In the case of symmetric information, the quality of the new product, $q^{\mathrm{I}}+\gamma$, is perfectly known by consumers before consumption choices.
- Stage 2. Both firms, the entrant and the incumbent, compete à la Bertrand. We note $P^{j}_{2,i}$, the price in stage 2 of firm j ($j=\mathrm{E,I}$) on market i ($i=\mathrm{N,S}$).
- Stage 3. Purchase is repeated: firms compete once more. Prices are $P^{j}_{3,i}$.

Relocation costs are assumed to be sufficiently high to prevent any relocation between stage 2 and stage 3. The game is solved by backward induction. Let $\pi(l,\gamma)$ denote the one period profit and $\Pi(l,\gamma)$ the whole profit over the two periods[2] of firm E if it locates in region l and if the innovation size is γ. First, assume that, at the end of stage 1, E is also located in N. In stage 3, on the northern market, as in standard Bertrand competition with asymmetric cost, the most efficient firm (firm E)

[1]This amounts to assuming that the incumbent can serve market S. This assumption could be relaxed.

[2]Discount rate is assumed to be zero.

charges price $P_{\mathrm{N}}^{\mathrm{E},*} = \gamma$: a mark-up of γ (the innovation size) over the marginal cost of firm I (here equal to 0). Firm I charges its marginal cost: $P_{\mathrm{N}}^{\mathrm{I},*} = 0$.

We obtain the equilibrium price on the southern market using a similar reasoning: $P_{\mathrm{S}}^{\mathrm{E},*} = \gamma + \lambda$ (mark-up plus firm I's marginal cost equal to transport cost λ) and $P_{\mathrm{S}}^{\mathrm{I},*} = \lambda$. Consequently, the equilibrium profit level is

$$\pi(N,\gamma) = 2\gamma. \tag{2}$$

Second, suppose that firm E is located in region S. The equilibrium price on market S is $P_{\mathrm{S}}^{\mathrm{E},*} = \gamma + \lambda$ and $P_{\mathrm{S}}^{\mathrm{I},*} = \lambda$. Firm E could serve market N only if the innovation size is larger than the transportation cost. Thus the price-equilibrium is

$$P_{\mathrm{N}}^{\mathrm{E},*} = \begin{cases} \gamma, & \text{if } \gamma > \lambda, \\ \lambda, & \text{otherwise.} \end{cases} \tag{3}$$

Hence the equilibrium profit is

$$\pi(S,\gamma) = \begin{cases} 2\lambda, & \text{if } \gamma \geq \lambda, \\ \gamma + \lambda, & \text{if } \gamma \leq \lambda. \end{cases} \tag{4}$$

The second stage is similar to the third stage. Consequently, the whole profit of the incumbent is as follows:

- If firm E locates in region N, it serves both markets and earns

$$\Pi(N,\gamma) = 4\gamma, \tag{5}$$

- whereas if E locates in S, it serves market N only if the innovation size γ is high enough. The firm earns

$$\Pi(S,\gamma) = \begin{cases} 4\gamma, & \text{if } \gamma \geq \lambda, \\ 2(\gamma + \lambda), & \text{if } \gamma \leq \lambda. \end{cases} \tag{6}$$

Therefore, the entrant, when choosing its location, faces the following trade-off: locating in the North is the best way to serve both markets, whereas in the South competition is softer. We have the following result.

Proposition 1. *With complete information, when the incumbent firm is located in the North, the entrant locates in the South whenever innovation size is less than $\hat{\gamma}(\lambda) = \lambda$ and is indifferent otherwise.*

Proof. Trivial comparison of (5) and (6). □

As in standard location models (Fujita and Thisse, 1996, Section 4), competition plays a centrifugal role and results in a balanced location: if one region benefits from the leading firm, the entrant locates in the other region with positive probability. Note that no force induces the new entrant to prefer to locate in the North rather than in the South. We now contrast this outcome with locations under asymmetric information.

4. Location with asymmetric information

The timing is as before except that the quality of E is revealed to consumers only at the beginning of stage 3. Consumers revise their beliefs at the end of stage 2 according to the firms' strategies. Let $f(\gamma|P_2,l)$ represent those beliefs, where $P_2=(P^{\mathrm{E}}_{2,i},P^{\mathrm{I}}_{2,i})$ is the vector of prices of firms in stage 2 and l is the entrant location. The innovation size expected by consumers is therefore

$$E(P_2,l)=\int_0^{\bar{\gamma}}\gamma f(\gamma|P_2,l)\mathrm{d}\gamma.$$

The Perfect Bayesian Equilibrium of this game is defined in the following way:

Definition 1. A Perfect Bayesian Equilibrium is a vector of strategies $l^*(\gamma)$, $P_2^*(\gamma)$, $P_3^*(\gamma)$ and beliefs $f(\gamma|l^*,P_2^*)$ such that:

(i) $l^*,P_2^*,P_3^*\in\arg\max_{l,P_2,P_3}\pi(l,P_3,E(l^*,P_2^*))+\pi(l,P_3,\gamma)$.
(ii) Beliefs $f(\gamma|l^*,P_2^*)$ are revised according to a Bayesian rule if location l^* and prices P_2^* are observed and indeterminate otherwise.

Because quality is revealed at the beginning of stage 3, P_3^* is the equilibrium price of the price competition under symmetric information and $\pi(l,\gamma)$ is the one period profit determined in the last section.

Next, we prove in Appendix A that a Spence–Mirrlees condition holds, that is

$$\frac{\partial\Pi(N,\gamma)}{\partial\gamma}\geq\frac{\partial\Pi(S,\gamma)}{\partial\gamma}. \tag{7}$$

This inequality implies that spatial agglomeration is more harmful to profits when the innovation size is small. Hence, if for an innovation size $\tilde{\gamma}$, firm E is indifferent between both locations, E locates in the North whenever γ is larger than $\tilde{\gamma}$, and in the South otherwise.

Also, we prove (see Appendix A) that there is no price separating equilibrium (the price has no commitment value) so that location is the only way to signal quality. Therefore, we consider only semi-separating and pooling equilibria. In a semi-separating equilibrium, if the innovation size belongs to $[\tilde{\gamma},\bar{\gamma}]$, the new entrant locates in the North close to the incumbent, and otherwise in region S. In a pooling equilibrium the new entrant locates in the same region as the incumbent for any innovation size.

Let us first prove a preliminary result.

Lemma 1. *There is a threshold* $\overline{\gamma^m}(\lambda)$ *such that*:

(*i*) *If* $\gamma^m>\overline{\gamma^m}(\lambda)$, *two equilibria exist*:
- *a pooling equilibrium where both firms locate in N*;
- *a pooling equilibrium where both firms locate in S.*

(*ii*) *If* $\gamma^m<\underline{\gamma^m}(\lambda)$, *two equilibria exist*:

- *a semi-separating equilibria in which firm E locates in the North whenever $\gamma > \tilde{\gamma}(\lambda)$, in the South otherwise*;
- *a pooling equilibrium in which the firm locates in the South for any innovation size*.

Proof. See Appendix A. □

As usual in signaling games, there are too many equilibria. To select one equilibrium, we refer to a slightly modified version (Umbhauer, 1994) of the 'K-undefeated' criterion (Mailath et al., 1993) that restricts out-of equilibrium beliefs. Both criteria are motivated by a forward induction logic. The criterion (Umbhauer, 1994) is as follows.

Definition 2. Umbhauer (1994). Let G^* and G^{**} be two equilibria, and $l^*(\gamma)$ and $l^{**}(\gamma)$ the equilibrium location of firm γ in equilibrium G^* and G^{**}. An equilibrium G^* 'defeats' G^{**} if there is a subset of innovation size Γ such that:

(i) $\Pi^*(\gamma) \geq \Pi^{**}(\gamma)$ for all $\gamma \in \Gamma$ and $\Pi^*(\gamma) < \Pi^{**}(\gamma)$ for all $\gamma \in [0,\bar{\gamma}] \setminus \Gamma$.
(ii) There are some γ that belong to Γ for which out-of-equilibrium beliefs $f^{**}(\gamma|.)$ that support G^{**} are such that

$$f^{**}(\gamma|l^*(\gamma)) \neq \frac{f(\gamma)}{\int_\Gamma f(s)\mathrm{d}s}. \tag{8}$$

In other words, if consumers observe an out-of-equilibrium location, their beliefs must be concentrated on the innovation size γ for which the firm prefers the equilibrium in which this particular location is indeed an equilibrium (point (i) above; note also that the criterion of Mailath et al. (1993) is less demanding: their point (i) would be $\Pi^*(\gamma) \geq \Pi^{**}(\gamma)$ for all γ and $\Pi^*(\gamma) > \Pi^{**}(\gamma)$ for all $\gamma \in \Gamma$). The equilibrium is defeated if condition (i) on out-of-equilibrium beliefs no longer supports the equilibrium.

This refinement selects one equilibrium in cases (i) and (ii) of Lemma 1. Hence the following proposition.

Proposition 2.

(*I*) *Asymmetric information induces agglomeration*: *whenever the innovation size is larger than $\tilde{\gamma}(\lambda,\gamma^m) < \hat{\gamma}$, both firms locate in the same region.*
(*II*) *When transport cost λ is low* (*less than γ^m*), *the new entrant always locates in the North, whatever its innovation size*: $\tilde{\gamma}(\lambda,\gamma^m) = 0$.

Proof. (I) We first consider the case where $\gamma^{\mathrm{m}} < \overline{\gamma^{\mathrm{m}}}(\lambda)$. The criterion selects the semi-separating equilibrium G^* against the pooling equilibrium G^{**}. The proof is divided into two parts. In the first part, we define Γ, while the second part studies its properties.

(i) We note by γ^l a firm that gains as much in both equilibria. γ^l is such that

$$\Pi(N,E(N)) + \Pi(N,\gamma^l) = \Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\gamma^l). \tag{9}$$

First, note that firm of type $\bar{\gamma}$ earns more in the semi-separating equilibrium than in the pooling equilibrium (see Eq. (A.5)). Second, firm $\gamma=0$ earns more in the pooling equilibrium than in the separating equilibrium. Second, function $\Pi(N,E(N)) + \Pi(N,\gamma) - \Pi(S,\gamma^{\mathrm{m}}) - \Pi(S,\gamma)$ is both increasing and continuous in γ (Spence–Mirrlees condition). Hence the existence and uniqueness of γ^{l}. Therefore, there is a set Γ ($\Gamma=[\gamma^{l},\bar{\gamma}]$) of types that prefer the semi-separating rather than the pooling equilibrium.

Fig. 1 present the profits of a firm γ localized in N ($\Pi(N,E^{*}(N)) + \Pi(N,\gamma)$, semi-separating equilibrium) and in S ($\Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\gamma)$, pooling equilibrium). By definition, innovation γ^{l} is the intersection of curve $\Pi(N,E^{*}(N)) + \Pi(N,\gamma)$ and curve $\Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\gamma)$.

(ii) We check that out-of-equilibrium beliefs are 'inconsistent' according to (ii) of the last definition. Out-of-equilibrium beliefs that guarantee the existence of the pooling equilibrium G^{**}, $f^{**}(\gamma|N)$, are such that firm $\bar{\gamma}$ stays in S: beliefs are such that curve $\Pi(N,E^{**}(N)) + \Pi(N,\gamma)$ is below curve $\Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\gamma)$.

We must prove that out-of-equilibrium beliefs $f^{**}(\gamma|N)$ cannot be equal to $f(\gamma)/\int_{\Gamma} f(s)\mathrm{d}s$. It is sufficient to prove that $\gamma^{l} > E^{**}(N)$. In other words, firm γ^{l} has an incentive to deviate from region S to region N. So as to show $\gamma^{l} > E^{**}(N)$ we prove that curve $\Pi(N,\gamma^{l}) + \Pi(N,\gamma)$ is above curve $\Pi(N,E^{**}(N)) + \Pi(N,\gamma)$.

There exists a firm of type γ indifferent between N (when the anticipated innovation is γ^{l}) and S (when the anticipated innovation is γ^{m}):

$$\Pi(N,\gamma^{l}) + \Pi(N,\gamma) = \Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\gamma). \tag{10}$$

Indeed, γ^{l} exists whatever $E^{*}(N)$. If $E^{*}(N)=\gamma^{l}$, γ exists and is such that

$$\Pi(N,\gamma^{l}) + \Pi(N,\gamma) = \Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\gamma). \tag{11}$$

In other words, curve $\Pi(N,\gamma^{l}) + \Pi(N,\gamma)$ and curve $\Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\gamma)$ intersect. Consequently, $E^{**}(N) < \gamma^{l}$. Elimination of the pooling equilibrium in N against the pooling equilibrium in S proceeds in the same way.

(II) When $\lambda < \gamma^{\mathrm{m}}$, (A.7) implies $\tilde{\gamma}=0$. □

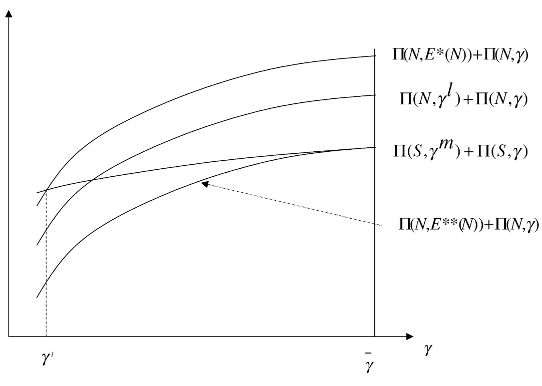

Fig. 1. Existence of γ^{l} (in exponent).

Spatial agglomeration arises from information asymmetry. Indeed, the new entrant faces the following trade-off. On the one hand, according to the Spence–Mirrlees condition, spatial agglomeration mainly hurts the poorly innovating firm (γ low). Hence consumers expect high quality from a firm that locates in region N. On the other hand, region S benefits from less competition. Hence, if the innovation size is high enough, the new entrant locates in region N and faces tough competition in order to signal its large innovation size.

Contrary to what occurs with complete information, competition is a centripetal force: the new leader could eventually benefit from tough competition as it allows quality signaling. The presence in the North of the current leader is not a drawback for region N to attract new firms. This result stresses the importance of history in the location process. The North benefits from the presence of the incumbent. There is a self-reinforcing mechanism due to quality signaling.

Furthermore, if the transportation cost is low enough, the new entrant is locked in the North whatever the innovation size and this could eventually lead to regional inequalities. Indeed, consider a decrease in transport cost. This means more competition in region S. Therefore, the previous type indifferent between the two locations $\tilde{\gamma}(\lambda)$ switches from region S to region N. A large cost decrease could induce the new entrant to always locate in the North close to its competitor.

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Appendix A. The Spence–Mirrlees condition

If $\gamma > \lambda$

$$\frac{\partial \Pi(N,\gamma)}{\partial \gamma} = 2 = \frac{\partial \Pi(S,\gamma)}{\partial \gamma},$$

and if $\gamma < \lambda$

$$\frac{\partial \Pi(N,\gamma)}{\partial \gamma} = 2 > 1 = \frac{\partial \Pi(S,\gamma)}{\partial \gamma}.$$

No price separating equilibrium

Assume that firm E locates in N whenever γ belongs to $[\gamma_1, \bar{\gamma}]$ with $\gamma_1 > 0$. First consider market N. We prove that no separating equilibrium in which price signals quality exists. We denote $P(\gamma)$ the price of E of type γ. Its profit is therefore

$$\Pi(P(\gamma)) = \begin{cases} P(\gamma), & \text{if } P(\gamma) < \gamma, \\ \frac{1}{2}P(\gamma), & \text{if } P(\gamma) = \gamma, \\ 0, & \text{otherwise.} \end{cases} \tag{A.1}$$

In a price separating equilibrium, so as to prevent any deviation, profit must be the same whatever the type revealed. The only price profile candidate is therefore

$$P(\gamma) = \gamma + \eta,\ \ \eta > 0, \tag{A.2}$$

$$f(\gamma/P) = 1 \text{ if } P = P(\gamma) \text{ and } 0 \text{ otherwise.} \tag{A.3}$$

Nevertheless, there are no beliefs that support such an equilibrium if a price P belonging to $[0,\gamma_1]$ is observed. In that case, a firm has incentives to deviate from the above equilibrium whatever the anticipation and enjoy a positive profit. When $\gamma_1 = 0$, the firm is induced to change its location. For market S or a location in S, the proof proceeds in the same way.

Proof of Lemma 1. (i) A semi-separating equilibrium exists if there is a firm of type $\tilde{\gamma}$ indifferent between N and S:

$$\Pi(N,E(N)) + \Pi(N,\tilde{\gamma}) = \Pi(S,E(S)) + \Pi(S,\tilde{\gamma}). \tag{A.4}$$

We check that $\tilde{\gamma}$ belongs to $[0,\overline{\gamma}]$. The best innovator (firm $\overline{\gamma}$) has an incentive to signal its quality by locating in the North. Indeed:

$$\Pi(N,\overline{\gamma}) + \Pi(N,\overline{\gamma}) = \Pi(S,\overline{\gamma}) + \Pi(N,\overline{\gamma}) > \Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\overline{\gamma}). \tag{A.5}$$

Moreover, firm $\gamma = 0$ must locate in S. It is the case if

$$\Pi(N,\gamma^{\mathrm{m}}) + \Pi(N,0) \leq \Pi(S,0) + \Pi(S,0), \tag{A.6}$$

iff

$$2\gamma^{\mathrm{m}} < 2\lambda \text{ iff } \gamma^{\mathrm{m}} < \lambda = \overline{\gamma^{\mathrm{m}}}. \tag{A.7}$$

Moreover, $\Pi(N,E(N)) + \Pi(N,\tilde{\gamma}) - \Pi(S,E(S)) - \Pi(S,\tilde{\gamma})$ is both increasing and continuous in $\tilde{\gamma}$ (Spence–Mirrlees condition). Therefore, if inequality (A.7) holds, $\tilde{\gamma}$ exists.

(ii) There exists a pooling equilibrium in S if, whatever its type, firm E has no incentive to deviate from region S to region N. From equilibrium beliefs, $E(N)$ must be such that firm $\overline{\gamma}$ does not deviate:

$$\Pi(N,E(N)) + \Pi(N,\overline{\gamma}) < \Pi(S,\gamma^{\mathrm{m}}) + \Pi(S,\overline{\gamma}). \tag{A.8}$$

That is the case whenever $E(N) < \gamma^{\mathrm{m}}$.

(iii) In the same way, there exists a pooling equilibrium in N if the new entrant always locates in N. From equilibrium beliefs, $E(S)$ must be such that firm $\gamma = 0$ does not deviate:

$$\Pi(N,\gamma^{\mathrm{m}}) + \Pi(N,0) > \Pi(S,E(S)) + \Pi(S,0). \tag{A.9}$$

If $\gamma^{\mathrm{m}} < \overline{\gamma^{\mathrm{m}}}(\lambda)$, there are no beliefs that support the former inequality. However, if $\gamma^{\mathrm{m}} > \overline{\gamma^{\mathrm{m}}}(\lambda)$, the inequality is true whenever $E(S) < \gamma^{\mathrm{m}} - \lambda$. □

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