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5

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Locational Choice in a Duocentric Urban System (with an application to the Portuguese economy)*

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resumo

Num sistema urbano duocêntrico em que as cidades são portuárias e uma delas é uma capital, duas empresas enfrentam um *trade-off* entre minimizarem o custo de transporte a um porto e minimizarem a distância entre as empresas a fim de beneficiarem de exterioridades espaciais. O conceito de equilíbrio de Nash não é satisfatório neste contexto, porque os equilíbrios são múltiplos e nenhum deles é simétrico. Com efeito, aglomerar-se em cada cidade portuária é um equilíbrio de Nash para ambas as empresas. Se adoptarmos o conceito de equilíbrio local de Nash, surgem novos equilíbrios simétricos para cada conjunto de valores dos parâmetros. Se os custos de transporte predominam, cada empresa localiza-se num porto; se as economias de aglomeração predominam, as empresas juntam-se num ponto arbitrariamente próximo do centro do mercado, do lado da cidade que não é a capital. Se os custos de transporte decrescem, o sistema urbano duocêntrico tende para um sistema tricêntrico, com um terceiro centro onde as empresas se aglomeram. O decréscimo de custos de transporte entre as cidades de Lisboa e Porto cria a possibilidade de se localizar um conjunto de infraestruturas comuns num ponto intermédio.

résumé / abstract

Dans un système urbain à deux centres, où les deux villes sont des ports et l'une d'elles est une capitale, deux entreprises doivent choisir entre minimiser le coût de transport vers un port et minimiser la distance entre les deux entreprises afin de bénéficier "d'externalités spatiales". Le concept d'équilibre de Nash n'est pas ici satisfaisant car les équilibres sont multiples et aucun n'est symétrique: se regrouper dans chacune des deux villes portuaires est un équilibre de Nash pour les deux entreprises. Si nous adoptons le concept d'équilibre local de Nash, de nouveaux équilibres symétriques surgissent pour chaque configuration de valeurs des paramètres. Si les coûts de transport dominent, chaque entreprise s'établit dans un port; si les économies d'agglomération sont prédominantes, les entreprises se regroupent sur un site arbitrairement proche du centre du marché, du côté de la ville qui n'est pas une capitale. Si les coûts de transport décroissent, on passe d'un système à deux centres à un système à trois centres, où les entreprisent se concentrent. La baisse des coûts de transport entre les villes portugaises de Lisbonne et Porto ouvre la possibilité de localiser un ensemble d'infrastructures communes sur un site intermédiaire.

In a duocentric urban system, where the towns are port-cities and one is a capital, two firms face a trade-off between minimizing transport costs to a port and minimizing inter-firm distance in order to benefit from spatial externalities. The concept of Nash equilibrium is unsatisfactory here because equilibria are multiple and none is symmetric: to cluster in each port-city is a Nash equilibrium for both firms. If we adopt the concept of local Nash equilibrium, new symmetric equilibria arise for each set of values of parameters. If transport costs dominate, each firm locates in a port; if economies of agglomeration dominate, the firms cluster in a point arbitrarily near to the centre of the market, closer to the city which is not a capital. If transport costs decrease, a duocentric urban system tends to a tricentric system with a third centre where firms agglomerate. The decrease of transport costs between the Portuguese cities of Lisbon and Oporto creates the possibility of locating a set of common infrastructures in an intermediate point.

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1 — Introduction

In this paper, we purport to describe the competitive locational behaviour of two firms in a duocentric urban system. The spatial setting is inspired by the Portuguese economy, which is organized around two port-cities, Lisbon and Oporto. Basically, we assume that each firm faces a trade-off between minimizing transport costs to a port and benefiting from spatial externalities which decrease with interfirm distance. In order to focus on locational competition in a Weberian sense, we assume that the firms charge parametric common uniform delivered prices, so that only locations are chosen non-cooperatively and firms bear all transport costs.

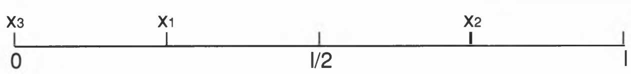
If we adopt the usual Nash concept of equilibrium, multiple equilibria arise. However, the problem does not follow so much from multiplicity but rather from the lack of *"focal points"* in the sense of Schelling (1960)[1]. In the setting of a space organized almost symmetrically around two cities (although one of the cities is a capital and the other one is slightly more populated), only symmetric locations are *"focal"*. Instead of resorting to mixed strategies (such as in Farrell, 1987), we dealt with multiplicity of equilibria by broadening the concept of non-cooperative equilibrium so that symmetric equilibria could arise. We adopted the concept of local Nash equilibrium[2], a pair of strategies (locations) which resists unilateral deviations in a neighbourhood of equilibrium. This choice was also dictated by the specific characteristics of locational competition. Empirical evidence shows that spatial changes are usually limited to small neighbourhoods of the previous locations.

2 — The model

Suppose that a country is spatially represented by the interval [0,l]. Following Xiao-Ping Zheng (1990), we assume that there are two port-cities located at the end-points of the interval.

There are three business firms: firm 3 is a higher order firm and firms 1 and 2 are low-order firms in an urban hierarchy. Moreover, firm 3 has its location fixed at x = 0 (the *"capital city"*), but the other locations, x_1 and x_2, are variable.

Figure 1. Location Line



Firms 1 and 2 import an input through the nearest port at wholesale price P_W, process it and distribute it to consumers at a parametric uniform delivered price $\bar{p}$. Moreover, we assume a fixed proportions technology in which one unit of input is transformed into one unit of output with a zero processing cost. The assumption of a parametric price enables us to concentrate on locational competition (instead of price competition), thereby following the traditional approach in locational models (Eaton and Lipsey, 1975).

The assumption of a uniform delivered price instead of f.o.b. mill price means that the firms bear all transport costs so that profit maximizing locations are identical to transport cost minimizing locations (Gabszewicz and Thisse, 1986) and a Weberian setting can be adopted.

We assume that the city at 0 has $2P_1$ consumers and the city at l has $2P_2$ with $P_2 \geq P_1$, but $|P_1 - P_2|$ is arbitrarily small so that the distribution between towns is *"balanced"*. Density of consumers outside towns in (0,l) is zero[3]. At the parametric price $\bar{p}$, each consumer buys one unit of product per unit of time[4]. Therefore, each firm sells a constant quantity $\bar{q} = P_1 + P_2$.

1 This is why the usual procedure of "refining" the equilibrium concept was not useful here.
2 See, on this issue, Neven (1986).
3 Or arbitrarily close to 0.
4 We can suppose that $\bar{p}$ is the consumer's reservation price.

There are spatial externalities among the firms in the sense of Fujita and Ogawa (1982): each firm must communicate regularly with the others. Each firm with variable location bears a transaction or communication cost which is proportional to the distance to the other two firms.

Let x_i, x_j be the locations of firms 1,2. Then, the communication cost for firm k=i, j per unit of output is cD_k where D_k is communication distance. Parameter c measures the strength of agglomerative forces. For $x_j \geq x_i$, i,j =1, 2, distances of communication are,

$$D_j = x_j + (x_j - x_i) = 2x_j - x_i \quad (1)$$

$$D_i = (x_j - x_i) + x_i = x_j$$

Profit function of firm j (j=1,2) is,

$$\pi_j(x_i,x_j)=\bar{p}\,\bar{q} - t_1\bar{q}\ \min\{x_j, l - x_j\} - c\,D_j(x_i,x_j) - t_2\,P_1\,x_j - t_2\,P_2\,(l - x_j) \quad (2)$$

In expression (2), $\bar{p}\,\bar{q}$ are the revenues of the firm and the other terms are different kinds of costs:

1) Transport cost of the input from the nearest port

$t_1\ \bar{q}\ \min\{x_j, l - x_j\}$

where t_1 is the unit transport cost of the input;

2) Inter-firm communication costs

$c\ D_j(x_i,x_j)$

3) Transport costs of the output to town at 0

$t_2\ P_1\ x_j$

where t_2 is the unit transport cost of the output.

4) Transport cost of the output to town at l

$t_2\ P_2\ (l - x_j)$

Setting $\bar{q} = 1$ (by adopting a convenient unit of measure) and solving (2) we get,

$\pi_j(x_i,x_j) = \bar{p} - t_1\ \min\{x_j, l - x_j\} - c\ D_j(x_i,x_j) - t_2\ x_j\ (P_1 - P_2) - w$, where $w = t_2\ P_2\ l$ is a constant.

Clearly, to maximize $\pi_j(x_i,x_j)$ w.r.t. x_j is equivalent to minimize $Tj(x_i,x_j)$, the aggregate cost supported by firm j w.r.t. xj:

$$T_j(x_i,x_j) = t_1\ \min\{x_j, l - x_j\} + c\ Dj(x_i,x_j) + t_2\ x_j\ (P_1 - P_2) + w, \quad (3)$$

where $|P_1 - P_2|$ is arbitrarily small.

Clearly, we have here a Weberian setting (Weber, 1929-1957): the mobile firms face a trade-off between locating separately at minimum transport cost points (the port-cities) or choosing joint locations that yield agglomeration economies.

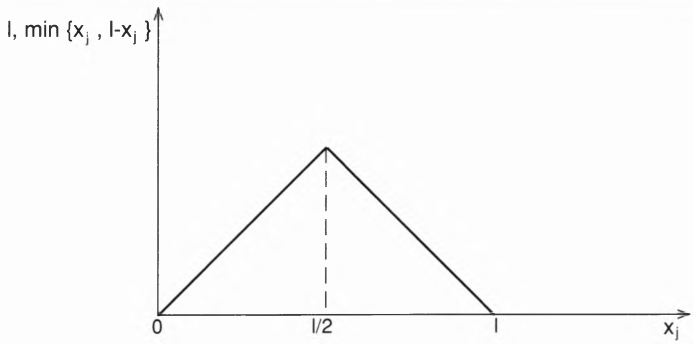
3 — Nash equilibria

We have defined a game with two players, the mobile firms x_1 and x_2. Each firm has the closed interval [0,l] as the strategy set. Payoff functions are $- T_j(x_i,x_j)$ and $- T_i(x_i,x_j)$, where $T_j(x_i,x_j)$ is defined by (3) and $T_i\ (x_i,x_j)$ by

$$T_i\ (x_i,x_j) = t_1\ \min\ \{x_i, l - x_j\} + c\ D_i\ (x_i,x_j) + t_2\ x_i\ (P_1 - P_2) + w \quad (4)$$

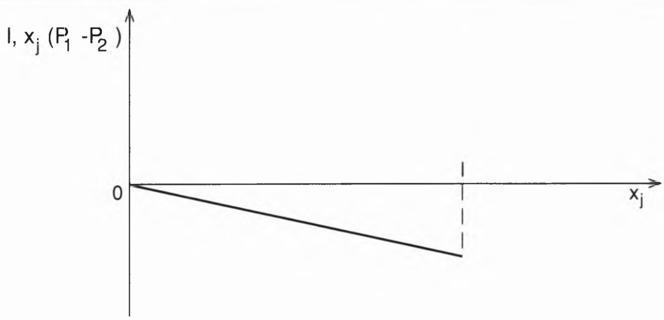
It is easy to find Nash equilibria because the aggregate cost is the sum of continuous functions which are either concave or can be decomposed in concave pieces.

Figure 2. Transport cost to port function



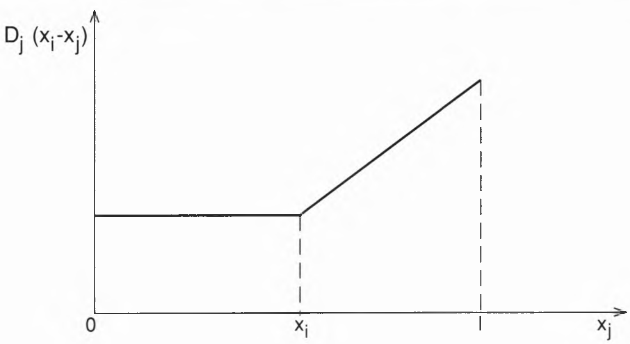
Transport cost to port function is concave

Figure 3. Transport cost to consumers function



Transport cost to consumers is linear (therefore concave)

Figure 4. Communication cost function



Communication cost function is convex but is composed by two linear (hence concave) pieces.

It is known that the global minimum of a concave function which is defined over a closed interval is reached in one of the boundary points of the interval.

We first check whether $(x_1^*, x_2^*) = (0,0)$ is a Nash equilibrium. Assume that $x_i = 0$. This implies that $x_i < x_j$ for all x_j and, consequently, communication costs among firms is $c\ D_j = 2\ c\ x_j$, hence linear and concave. Therefore, the aggregate cost function of firm $_j$ is

$T_j(0, x_j) = t_1\ x_j + 2\ c\ x_j + t_2\ (P_1 - P_2)\ x_j + w, \qquad x_j \leq l/2$

$T_j(0, x_j) = t_1\ (l - x_j) + 2\ c\ x_j + t_2\ (P_1 - P_2)\ x_j + w, \qquad l/2 < x_j < l$

$T_j(0,x_j)$ is the sum of concave functions in x_j; hence, it is concave. To find its minimum we must compare $T_j(0,0)$ and $T_j(0,l)$. We have

$T_j(0,0) \leq T_j(0,l) \Leftrightarrow 2\ c \geq t_2\ (P_2 - P_1)$

which holds because $P_2 - P_1$, although positive, is arbitrarily small. Therefore, (0, 0) is a Nash equilibrium.

Similarly, it is easy to check whether $(x_1^*, x_2^*) = (l,l)$ is a Nash equilibrium. In this case, communication cost is c l for any location of j. Aggregate cost function of firm j, given that $x_i = l$, is

$T_j(l, x_j) = t_1\ x_j + cl + t_2\ (P_1 - P_2)\ x_j + w, \qquad x_j \leq l/2$

$T_j(l,x_j) = t_1 (l - x_j) + c\ l + t_2\ x_j\ (P_1 - P_2) + w, \qquad l/2 < x_j \leq l$

Comparing the extrema of $T_j(l,x_j)$, we get

$T_j(l,0) = cl+w \geq T_j(l,l)=cl+t_2(P_1 - P_2)l+w$

which holds because $P_1 < P_2$. $(x_1^*, x_2^*) = (l, l)$ is a Nash equilibrium.

In order to check for other equilibria, we assume that $x_i = a$. Communication cost function is concave in [0, a] and [a, l], but not in [0, l]. Therefore, the minimum of $T_j(a, x_j)$ is reached either in 0 or in a or in l. $T_j(a,a)$, $T_j(a,0)$ and $T_j(a,l)$ are defined by (from (3)):

$T_j(a, a) = t_1\ a + c\ a + t_2\ a\ (P_1 - P_2) + w, \qquad 0 < a \leq l/2$

$T_j(a, a) = t_1\ (l - a) + c\ a + t_2\ a\ (P_1 - P_2) + w, \qquad l/2 \leq a < l$

$T_j(a,0) = c\ a + w$

$T_j(a,l) = c\ (2\ l - a) + t_2\ l\ (P_1 - P_2) + w$

The inequality $T_j(a,a) > T_j(a,0)$ yields

$t_1\ a + t_2\ a\ (P_1 - P_2) > 0$ for $0 < a \leq l/2$

$t_1\ (l - a) + t_2\ a\ (P_1 - P_2) > 0$ for $l/2 \leq a < l$,

which holds because $|P_1 - P_2|$ is arbitrarily small.

Therefore, for every a, point (a, a) is not a Nash equilibrium. Without increasing communication cost, each firm in a joint location decreases transport cost to a port by locating in 0.

On the other hand, $T_j(a,x_j)$ reaches its minimum in $x_j = 0$ as $T_j(a, 0) < T_j(a, l)$. This inequality implies

$2\ c\ (l - a) + t_2\ l\ (P_1 - P_2) > 0,$

which holds because a e [0,l] and $|P_1 - P_2|$ is arbitrarily small. This fact shows that no Nash equilibrium exists besides those where both firms agglomerate in a port-city.

4 — Local Nash Equilibria

The outcome above is quite trivial: in equilibrium, both firms agglomerate in a port-city, thus avoiding the trade-off between transport costs and agglomeration economies.

This outcome is not satisfactory because equilibrium is not unique. However, the problem does not lie in multiplicity in itself but rather in the absence of *"focal points"* among equilibria. Schelling (1960) stressed the importance of *"focal points"* to which players' expectations converge in the following way:

"If we then ask what it is that can bring their expectations into convergence and bring the negotiations to a close, we might propose that it is the intrinsic magnetism of particular outcomes, especially those that enjoy prominence, uniqueness, simplicity, precedent, or some rationale that makes them qualitatively differentiable from the continuum of possible alternatives" (Schelling, 1960: 70).

In the almost-symmetric space [0,l], symmetry of firms' locations with relation to l/2 is the intuitive property of a "focal point". Instead of refining the concept of non-cooperative equilibrium or resort to mixed strategy equilibrium, we should rather broaden it so that symmetric equilibria in pure strategies exist.

An alternative concept of equilibrium is local Nash equilibrium (LNE). If $\pi_1\ (x_1,x_2)$ and $\pi_2\ (x_1,x_2)$ are the payoffs of firms 1 and 2 or functions of pure strategies x_1, x_2, a pair (x_1^*, x_2^*) is an LNE iff

$\pi_1(x_1^*, x_2^*) \geq \pi_1(x_1, x_2^*)$ for $x_1 \in N_e\ (x_1^*)$

$\pi_1(x_1^*, x_2^*) \geq \pi_1(x_1^*, x_2)$ for $x_2 \in N_e\ (x_2^*)$

where $N_e\ (x_1^*)$ (respectively, $N_e\ (x_2^*)$) is a neighborhood of x_1^* (respectively, x_2^*).

There is an additional reason to adopt the concept of LNE instead of Nash equilibrium. Empirical evidence of spatial behavior shows that locational adjustments take place in a (usually small) neighborhood of existing locations. Also, it is the concept used in Hotelling's (1929) spatial competition model.

Clearly, to be a Nash equilibrium is a sufficient condition for an LNE. Therefore, $(x_1^*, x_2^*) = (0, 0)$ and $(x_1^*, x_2^*) = (l,l)$ are LNE for any parameter values.

With regard to LNE which are not Nash equilibria, we can demonstrate the following propositions.

Proposition 1: Location pairs $x_1^* = x_2^* = a$, with $l/2 < a \leq l$ are LNE iff $t_1 < 2\,c + t_2\,(P_1 - P_2)$

Proof: When $x_1^* = x_2^* = a$ with $l/2 < a \leq 1$, any relocation by firm j to the left of a implies an increase in transport costs to ports (because firms use port in l) and in transport costs to consumers (because $P_1 - P_2 \leq 0$). On the other hand, a relocation to the right of a (for $a < l$) has an effect on total costs with the same intensity but a symmetrical sign.

The aggregate cost function for firm j ($i \neq j$) if $x_i = a \in [l/2,l)$ is given by the following expression:

$T_j(x_i,x_j) = t_1\ (l - x_j) + c\ (2x_j - x_i) + t_2\, x_j\ (P_1 - P_2) + w, \qquad x_j \in (x_i,l]$

$T_j(x_i, X_j) = t_1(l\ -\ x_j) + c\ x_i + t_2\, x_j\ (P_1 - P_2) + w, \qquad x_j \in [l/2, x_i)$

Locations $x_1^* = x_2^* = a$ are a local Nash equilibrium iff,

$$\frac{\partial T_j}{\partial x_j} > 0, \qquad x_j \in (x_i,l]$$

$$\frac{\partial T_j}{\partial x_j} < 0, \qquad x_j \in [\,l/2,\ x_i)$$

Together, these two conditions mean that $t_1 > t_2\ (P_1 - P_2)$, which is met because $P_1 < P_2$ and $t_1 < 2\,c + t_2\,(P_1 - P_2)$.

Q.E.D.

Proposition 2: If $t_1 < 2c+t_2(P_1 - P_2)$, location pairs other than (0,0), (l,l) and (a, a) with $a \in (l/2,l)$ are not LNE.

Proof: W.l.g. assume that $x_j^* \leq x_i^*$. Suppose first that $x_j^* > 0$. Then, if $x_j^* \in (0,l/2]$, firm j's cost function is

$$T_j(x_i, x_j) = t_1 x_j + c x_i + t_2 x_j (P_1 - P_2) + w$$

A movement to the left by firm j is profitable iff:

$$\frac{\partial T_j}{\partial x_j} = t_1 + t_2(P_1 - P_2) > 0$$

which holds because $|P_1 - P_2|$ is arbitrarily small. Therefore, (x_i^*, x_j^*) is not an LNE.

For $x_j^* < x_i^*$ with $x_j^* \in (l/2, l)$, a relocation to the right by firm j decreases transport costs (both to port and to consumers) and does not change communication costs among firms: therefore (x_i^*, x_j^*) is not an LNE.

If $x_j^* = 0$, we have two distinct cases:

a) $x_i^* \in (0,l/2]$ and firm i's cost function is

$$T_i(x_i, x_j) = t_1 x_i + 2 c x_i + t_2 x_i (P_1 - P_2) + w$$

so that,

$$\frac{\partial T_i}{\partial x_i} = t_1 + 2c + t_2(P_1 - P_2) > 0 \qquad \text{for } x_i \in (0, l/2)$$

which holds because $|P_1 - P_2|$ is arbitrarily small. Therefore, firm i decreases its cost by moving towards 0, so that (x_i^*, x_j^*) is not an LNE.

b) $x_i^* \in [l/2, l]$. Then we have,

$$T_i(x_i,x_j) = t_1 (l - x_i) + 2cx_i + t_2 x_i (P_1 - P_2) + w$$

and

$$\frac{\partial T_i}{\partial x_i} = -t_1 + 2c + t_2(P_1 - P_2) > 0 \qquad \text{for } x_i \in (l/2, l]$$

which holds by assumption. Therefore, firm i decreases aggregate cost by moving to the left, so that (x_i^*, x_j^*) is not an LNE.

Q.E.D.

Proposition 3: Iff $t_1 > 2c + t_2(P_1 - P_2)$, $(x_i^*, x_j^*) = (0,l)$ is a local Nash equilibrium.

Proof: Let $x_j = 0$ and $x_i = l$. Firm i's cost function is

$$T_i(x_j, x_j) = t_1 (l - x_i) + 2 c x_i + t_2 x_i (P_1 - P_2) + w$$

and

$$\frac{\partial T_i}{\partial x_i} = -t_1 + 2c + t_2(P_1 - P_2) \qquad \text{for } x_i \in (l/2, l)$$

Condition for non-profitability of move by firm i is

$$\frac{\partial T_i}{\partial x_i} < 0 \iff -t_1 + 2c + t_2(P_1 - P_2) < 0$$

which holds by assumption.

Firm j's cost function is

$T_j(x_i,x_j) = t_1 x_j + c x_i + t_2 x_j (P_1 - P_2) + w$

and

$$\frac{\partial T_j}{\partial x_j} = t_1 + t_2(P_1 - P_2) > 0 \quad \text{for} \quad x_j \in (0\ , l/2)$$

which holds because $|P_1 - P_2|$ is arbitrarily small.

Q.E.D.

Proposition 4: If $t_1 > 2c + t_2 (P_1 - P_2)$, (x_i,x_j) other than (0,0), (l,l) and (l,0) is not an LNE.

Proof: W.l.g. assume that $x_j \le x_i$. Assume first that $x_j < x_i$. If $x_j > 0$, firm j can decrease its transport cost by moving towards the nearest port, without increase in communication distance and the variation in transport costs to consumers is arbitrarily small. If $x_j = 0 < x_i < l$, we have two cases:

a) If $0 < x_i \le l/2$, firm i's cost function is

$T_i(x_i, x_j) = t_1 x_i + 2c x_i + t_2 x_i (P_1 - P_2) + w$

and

$$\frac{\partial T_i}{\partial x_i} = t_1 + 2c + t_2(P_1 - P_2) > 0 \quad \text{for} \quad x_i \in (0,\ l/2)$$

because $|P_1 - P_2|$ is arbitrarily small.

Firm i decreases its cost by approaching port in 0.

b) If $l/2 \le x_i < l$, cost function is,

$T_i(x_i, x_j) = t_1 (l - x_i) + 2c x_i + t_2 x_i (P_1 - P_2) + w$

and

$$\frac{\partial T_i}{\partial x_i} = -t_1 + 2c + t_2(P_1 - P_2) < 0 \quad \text{for} \quad x_i \in (l/2\ , l)$$

which holds by assumption. Firm i decreases its cost by approaching to port in l.

Assume then that $x_j = x_i$. If $x_j = x_i = a \in [0,l/2]$, firm j can decrease its transport cost to port by moving to the left, without increasing communication costs and only marginally increasing transport cost to consumers. If $x_j = x_i = a \in [l/2,l]$, firms i's cost function is

$T_i(x_i, x_j) = t_1 (l - xi) + c (2x_i - x_j) + t_2 x_i (P_1 - P_2) + w$

so that

$$\frac{\partial T_i}{\partial x_i} = -t_1 + 2c + t_2(P_1 - P_2) < 0 \quad \text{for} \quad x_i \in (l/2\ , l)$$

by assumption, firm i decreases its cost by moving to the right.

Q.E.D.

We can summarize propositions 1 to 4 by saying that agglomeration at the ports is always a local Nash equilibrium. However, there are additional equilibria. If transport costs are high with respect to communication costs, we have an equilibrium with a firm in each port. If the opposite prevails, every point in (l/2,l) is an LNE.

The advantage of broadening the equilibrium concept is that we have now a unique symmetric equilibrium for each value of the parameters: (0,l) when transport costs are high and

$(l/2 + \varepsilon, l/2 + \varepsilon)$[5] with $\varepsilon > 0$ arbitrarily small if agglomeration economies prevail. This means that either the duocentric structure is consolidated — when transport cost to ports are high — or a third intermediate centre can arise. It is obvious that if such a new centre arises it is also likely to become a port-city.

5 — Application to the Portuguese economy

The Portuguese economy is organized around two port-cities, Lisbon, which is the capital, and Oporto. Therefore, the spatial structure of the Portuguese economy is founded on the superior efficiency of water and air transportation with relation to transportation by land (Pontes,1990).

Simultaneous membership of Portugal and Spain in EEC has stressed the role of land transportation (both by road and railway) because trade barriers between the neighboring countries have been eliminated and big investments in infrastructures (highways, high-speed railways) have taken place.

Therefore, the transport costs by road between Lisbon and Oporto have been consistently reduced and there are plans to connect the two cities by a highspeed train. This decrease of transport costs would make agglomeration economies feasible, namely, the cities could benefit from common infrastructures located at an intermediate point between Lisbon and Oporto. A common airport could be an example: passengers would have to bear a larger transport cost by train to the airport, but they would benefit from a much denser schedule of flights to each destination.

6 — Conclusions

In a duocentric urban system, the firms trade-off transport costs to the ports and agglomeration economies which decrease with inter-firm distance. An obvious way for the firms to avoid this trade-off is to cluster in a port. This outcome is indeed a Nash equilibrium but there remains the problem of coordination to select a port-city. There is no *"focal"* equilibrium because each outcome is highly asymmetric. If we assume that the firms consider spatial adjustments only in the neighbourhood of existing locations (that is, if we use the concept of local Nash equilibrium), new equilibria arise, depending whether transport costs dominate economies of agglomeration or the inverse is true. If the former assumption holds, there is a symmetric equilibrium with each firm in a different portcity; if economies of agglomeration dominate transport costs, all clusters of firms in $(l/2,l)$ are equilibria. Among them we can select $(l/2 + \varepsilon, 1/2 + \varepsilon)$, (with $\varepsilon > 0$ arbitrarily small) as an almost symmetric equilibrium[6]. As a result, we have a symmetric equilibrium for all possible values of parameters. Although equilibria are multiple, players' expectations converge to the unique symmetric equilibrium.

If we assume that the decrease of transport costs is a steady trend in any urban system, we can infer that agglomeration of firms in an intermediate point between the port-cities will take place in order to allow economies of agglomeration. It is likely that a third centre will be formed, which is closer to port in l than to capital in 0, and will itself become a port-city.

5 Equilibrium in this case is almost symmetric.
6 The agglomerative point is closer to port-city in l than to the capital city in 0.

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