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Industrial Agglomeration under Cournot Competition

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ABSTRACT. – In a two-region model where regional incomes are endogenous and where firms compete *à la* Cournot, we first show that strategic interactions may induce firms to agglomerate in the initially developed region, if transportation costs are low or economies of scale high: in the region where more firms are established, price and individual market shares effects (intra-regional competition) are counterbalanced by higher global market shares and reduction in imports (inter-regional competition). It is then shown that a regional advantage in costs, productivity or size attracts the location of new firms in this region.

Agglomération de l'industrie en concurrence à la Cournot

RÉSUMÉ. – Dans un modèle à deux régions où les revenus régionaux sont endogènes et où les firmes se livrent à une concurrence à la Cournot, nous montrons que les interactions stratégiques peuvent inciter les firmes à se localiser dans la région où elles sont initialement les plus nombreuses, si les coûts de transport sont faibles ou les économies d'échelle élevées : les effets prix et part de marché individuelle (concurrence intra-régionale) sont compensés par une demande agrégée plus élevée et une réduction des importations (concurrence inter-régionale). Un avantage en coût, fixe ou marginal, en productivité ou en taille favorise aussi la localisation dans cette région.

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1 Introduction

This paper builds on recent work in economic geography that borrows ideas from international trade under imperfect competition to extend the standard analysis of location problems. In particular, this literature focuses on the centripetal forces that induce firms to agglomerate in a few places only, and on the centrifugal forces that incite them to separate (see FUJITA and THISSE [1997] for a survey). As argued by KRUGMAN [1995], the main difficulties in location theory lie in the assumed market structure. Fundamentally, economic geography needs imperfect competition and increasing returns, which can be nowadays better described using the new tools of industrial organization (see also SCOTCHMER and THISSE [1993]).

The purpose of this paper is to uncover some agglomeration forces which could be at work in the context of the European Union. In particular, how does liberalization of trade between regions belonging to different countries affect the locational pattern of firms which are now allowed to export freely? Will these firms concentrate in the few developed regions or will a more balanced industrial structure emerge? We also want to study the impact of asymmetries between regional conditions of production. For instance, the degree of scale economies may differ between regions because of regional infrastructures. Clearly, differences in regional wages and/or productivities are also critical in the choice of the location by firms.

The use of the DIXIT and STIGLITZ [1977] model of monopolistic competition [1] in a two-region model has been initiated by KRUGMAN [1991a] and [1991b]. This model presents a formalized version of the forward and backward linkages that induce agglomeration, especially those related to the preference for variety, and the trade-off between fixed production costs and transportation costs. Extensions and generalizations of this model are many (see FUJITA and THISSE [1997] for references).

In these models, the assumption of a large number of firms leads to neglecting any form of strategic interaction. Actually, strategic interactions seem to be central in the process of spatial competition. For instance, in a Hotelling's one-stage game where there is no price competition, the market share competition induces firms to agglomerate. But in the Hotelling's two-stage game with quadratic transportation costs (see d'ASPREMONT *et alii* [1979]), where firms first choose their location and then compete in prices, the incentives to move away from competitors to lessen price competition dominate the market share effect and firms maximize spatial differentiation. In other words, price competition is a strong centrifugal force. And, indeed, if price competition is relaxed, for instance if the goods are imperfect substitutes (see de PALMA *et alii* [1985]), firms may agglomerate. Under Cournot competition, where strategic interactions lead to less aggressive firms' reactions than in Bertrand's, agglomeration arises as in KRUGMAN and VENABLES [1990] and ANDERSON and NEVEN [1991] who consider partial equilibrium models. Thus, in the context of a two-region economy where

1. Which is discussed extensively in d'ASPREMONT *et al.* [1996]

regional incomes are endogenous and profits are distributed among local consumers, we study the impact of Cournot competition in order to investigate how strategic interactions may influence the agglomeration process.

Firms are allowed to export and new firms may locate in either region. Firms choose a location to maximize profits. The purpose of this paper is then to determine in which region new firms set up, this choice being conditional on asymmetries in production, and to determine under which conditions agglomeration in one region emerges. The first asymmetry considered is the number of firms initially located in each region, which may reflect the role of "history" in that it accounts for earlier decisions. Second, there may be asymmetries in marginal or fixed costs of production, in the productivity of labor and in the size of the regions.

Our assumptions also differ from existing models because one of our objectives is to study the impact of some characteristics of European economies. In particular, we believe that the European labor markets are more rigid than in the US for at least two reasons. First, wages are more rigid in Europe. To take this into account, we assume that they are completely fixed, so that unemployment typically arises in equilibrium. Though wages should be affected in the long run, we leave this important issue aside. Second, migrations between regions of different countries are very low in Europe. They are only slightly higher between regions of the same country (see Commission des Communautés Européennes [1991a] and [1991b]). We then assume that there are no migrations between regions. These two assumptions are certainly too extreme, but they allow us to simplify the analysis and to gain some important insights about the working of the European labor markets.

We first show that the strategic interactions that occur in Cournot competition may induce firms to agglomerate in the initially developed region, when transportation costs are low enough or when economies of scale are high, assuming identical cost conditions. *Price and individual market shares effects that lower the profit in the region where more firms are established are counterbalanced by higher global market shares and reduction in imports.* However, these effects are not the only ones at work. It is then showed that a regional advantage in costs, productivity or size, attracts the location of new firms in this region.

The paper is organized as follows. The model is presented in section 2. In sections 3 and 4, regions differ only by the number of firms. Section 3 analyzes the price, quantity and profit effects, and compares the regional profits in the short-run equilibrium. In section 4, we perform a static comparative approach on the number of firms. Free-entry, long-run equilibria are compared according to the values of the fixed costs and of the transportation costs. Section 5 studies the impact of asymmetries on the regional structure, while section 6 concludes.

2 The Model

The regions are labelled 1 and 2. We assume that the total population of each region, L_i, $(i = 1, 2)$, is constant: there are no human migrations between regions. It is composed of La_i farmers, Lm_i workers and $L_i - La_i - Lm_i$ unemployed. Two goods are produced in each region: a subsistence good, called A, produced in the agricultural sector by farmers, and a single homogenous manufactured good produced in the industrial sector by firms using a single input, workers.

In each region, the agricultural population produces the subsistence good under constant returns to scale and perfect competition. Hence profits in this sector are zero and the price of the agricultural good equals the agricultural wage. We take this price as *numéraire*, so all the prices of the economy are expressed in terms of the subsistence good. Consequently, the total income of farmers is also constant. Finally, this good is exported without any transportation costs, which ensures that its price and the marginal income of farmers are the same in both regions. We also assume that there is no intersectoral mobility: farmers cannot work in industry and the proportion of farmers in the total population is constant. The characteristics of this sector are the same as in KRUGMAN [1991a]. These hypotheses simplify the analysis.

The consumers located in region i buy the manufactured good only in their local market, called market i. The markets are assumed segmented, so that the prices in these markets, p_i, may differ. The manufactured good is produced by n_i ($n_i \geq 1$) firms located in each region i, called firms i. Firms are identical in each region, but may differ between regions. The unique factor of production is labor and its marginal productivity is g_i, assumed constant. As we explained in the introduction, the marginal cost of production, workers' wages in terms of agricultural good, w_i, is assumed to be rigid. Fixed production costs, which reflect economies of scale, are denoted f_i. A firm located in region i then produces a quantity q_{ii} for its local market (market i) and a quantity q_{ij} for its export market (market j). It bears transportation costs per unit, t, on exported quantities. Profits per firm in region i are given by:

$$\pi_i = p_i q_{ii} + (p_j - t) q_{ij} - w_i lm_i - f_i,$$

with $q_{ii} + q_{ij} = g_i lm_i$, where lm_i is employment per firm. The total labor demand in region i is determined by the size of the production: $Lm_i = n_i lm_i$. Because the number of potential workers is fixed (since there is no migration, it equals the difference between total population and farmers), unemployment or excess of labor demand may arise.

In the whole population, only farmers and workers earn an income and consume. Their utility is Cobb-Douglas: $U = C_m^{\mu} C_a^{1-\mu}$, where C_m and C_a are the consumptions in manufactured and agricultural good, respectively μ is a constant belonging to [0, 1]. This implies that the price-elasticity is equal to 1. If R_i is the regional income, the market i equilibrium condition is:

$$Q_i = \mu \frac{R_i}{p_i}, \tag{1}$$

where Q_i is the total quantity sold in market i: $Q_i = n_i q_{ii} + n_j q_{ji}$. R_i is the sum of farmers' and workers' wages and of total profits, which are assumed to be locally redistributed to the local population:

$$R_i = La_i + w_i Lm_i + n_i \pi_i.$$

In this section, we solve the model considering n_i as constant and exogenous: there is no free entry and profits may be strictly positive. This is the short-run equilibrium. We study in sections 4 and 5, how free entry influences n_i. Firms compete *à la* Cournot. We determine the unique symmetric Nash equilibrium of a one stage game where firms simultaneously take their decisions for both markets. A firm located in region i maximizes its profits by choosing the quantities it produces for both markets, $\widetilde{q}_{ii}$ and $\widetilde{q}_{ij}$, taking the quantities produced by the $(n_i - 1 + n_j)$ other firms as given. We assume that firms do not internalize their influence on regional income, R_i. Given the demand and production functions, profits are:

$$\pi_i = \left(\mu \frac{R_i}{Q_i} - \frac{w_i}{g_i}\right)\widetilde{q}_{ii} + \left(\mu \frac{R_j}{Q_j} - \frac{w_i}{g_i} - t\right)\widetilde{q}_{ij} - f_i,$$

with: $\begin{cases} Q_i = \widetilde{q}_{ii} + (n_i - 1)q_{ii} + n_j q_{ji} \\ Q_j = \widetilde{q}_{ij} + (n_i - 1)q_{ij} + n_j q_{jj} \end{cases}.$

The first-order conditions are:

$$\begin{matrix} (2) \\ \\ (3) \end{matrix} \qquad \begin{cases} \dfrac{\partial \pi_i}{\partial \widetilde{q}_{ii}} = 0 \\ \dfrac{\partial \pi_i}{\partial \widetilde{q}_{ij}} = 0 \end{cases} \Longleftrightarrow \begin{cases} p_i - \dfrac{w_i}{g_i} - \widetilde{q}_{ii}\dfrac{p_i}{Q_i} = 0 \\ p_j - \dfrac{w_i}{g_i} - t - \widetilde{q}_{ij}\dfrac{p_j}{Q_j} = 0 \end{cases}$$

The second-order conditions are satisfied.

We set $\widetilde{q}_{ii} = q_{ii}$ and $\widetilde{q}_{ij} = q_{ij}$ to obtain from equations (1), (2) and (3) a linear system of 6 equations that allows us to easily derive all prices and quantities in the symmetric equilibrium:

$$\text{(I)} \quad \begin{cases} p_1 = \dfrac{n_1 \frac{w_1}{g_1} + n_2\left(\frac{w_2}{g_2} + t\right)}{n_1 + n_2 - 1} \\ p_2 = \dfrac{n_1\left(\frac{w_1}{g_1} + t\right) + n_2 \frac{w_2}{g_2}}{n_1 + n_2 - 1} \\ \left((n_1 - 1)p_1 - n_1 \dfrac{w_1}{g_1}\right) q_{11} + n_2\left(p_1 - \dfrac{w_1}{g_1}\right) q_{21} = 0 \\ \left((n_2 - 1)p_2 - n_2 \dfrac{w_2}{g_2}\right) q_{22} + n_1\left(p_2 - \dfrac{w_2}{g_2}\right) q_{12} = 0 \\ n_1(1 - \mu)q_{11} - n_1 \dfrac{\mu}{p_1}(p_2 - t)q_{12} + n_2 q_{21} = \dfrac{\mu}{p_1}(La_1 - n_1 f_1) \\ n_2(1 - \mu)q_{22} - n_2 \dfrac{\mu}{p_2}(p_1 - t)q_{21} + n_1 q_{12} = \dfrac{\mu}{p_2}(La_2 - n_2 f_2) \end{cases}$$

The first two equations state that the price in a market is a constant mark-up on the average of the marginal costs of the firms producing for this market, weighted by their number. Substituting these equations in the following two gives the market share of a firm in each market. Finally, from the last two equations, we can compute the levels of production.

We now have to check that all quantities are positive, i.e. that firms effectively produce for both markets. It is clear that, if n_i tends towards infinity, p_i tends towards $\frac{w_i}{g_i}$. This means that, if $\frac{w_j}{g_j} + t > \frac{w_i}{g_i}$ and if n_i is high enough, a firm located in region j has a negative marginal profit on its exports and then does not produce for market i. Depending on the number of firms located in each region and on their relative marginal costs, we may then have corner solutions to the game. Figure 1 illustrate these different cases [2].

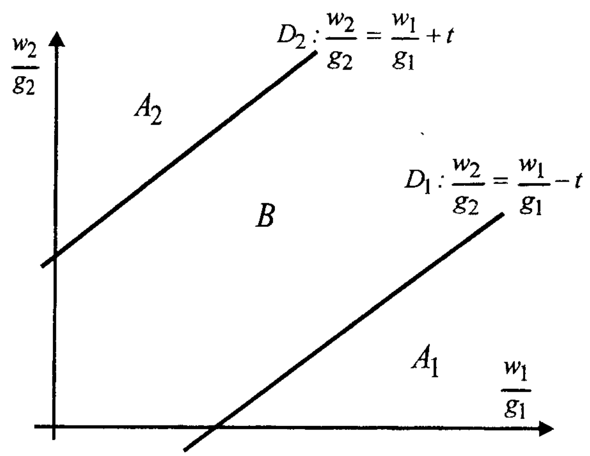

FIGURE 1

Areas of production.

We call "effective marginal cost" the ratio of nominal marginal cost on productivity. In area B, the effective marginal cost differential between regions is lower than the transportation cost. In this case, a firm always produces for its local market. But a firm i exports to the market j, only if the number of local firms, firms j, is lower than a maximum number called $\operatorname{Max} n_{ij}$: if $n_j > \operatorname{Max} n_{ij} = \frac{\frac{w_i}{g_i}+t}{\frac{w_i}{g_i}+t-\frac{w_j}{g_j}}$, then $q_{ij} = 0$.

In area A_i, the effective marginal cost differential is greater than the transportation cost and firms i are heavily disadvantaged. Firms j produce for both markets, whatever the number of firms. If $n_j < \operatorname{Max} n_{ij}$, firms in region i produce for both markets. If $\operatorname{Max} n_{ij} < n_j < \operatorname{Max} n_{ii} = \frac{\frac{w_i}{g_i}}{\frac{w_i}{g_i}-\left(\frac{w_j}{g_j}+t\right)}$, firms in region i produce only for their local market ($q_{ij} = 0$). If $\operatorname{Max} n_{ii} < n_j$, firms i do not produce at all ($q_{ij} = 0$ and $q_{ii} = 0$). The analytical solutions for the prices and quantities in equilibrium in the different cases are given in appendix 2.

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2. A more detailed presentation of this problem is given in appendix 1.

Finally, because there are fixed costs, a non-negativity constraint of profits has to be considered. The fact that wages are rigid also makes possible a saturation of the full-employment constraint. This means that the number of workers cannot be higher than the difference between the total population and the number of farmers. We do not present the analytical forms of these conditions here, but we will take them into account in the following sections. They both limit the number of firms that can be located in each region and they can be written:

$$\begin{cases} \pi_i \geq 0 \\ La_i + Lm_i \leq L_i. \end{cases}$$

In sections 3 and 4, we assume that we are in the case of area B in figure 1. In section 5, we discuss the case of areas A_i.

3 Regional Profits in the Short-Run Equilibrium

In this section, we assume that the two regions are identical in every respect except in the number of firms ($\frac{w_i}{g_i} = \frac{w_j}{g_j} = \frac{w}{g}$, $f_i = f_j$, $La_i = La_j$, $L_i = L_j$) and we determine in which region profits are higher in the short run, i.e. when there is no free entry. If profits are higher in the region where firms are more numerous, agglomeration emerges in the long run because new firms locate in this region. Recall that in Cournot competition between two non-identical firms, the production of the lowest cost firm is higher and that in Cournot competition between n identical firms, when n increases towards infinity, the price tends towards the marginal cost, the total quantity increases towards the competitive outcome, the quantity produced per firm decreases and profits tend towards zero. These effects interact in the model.

3.1. Price and Market Shares Effects

Strategic interactions act both as centripetal and centrifugal forces. First, the effects of Cournot competition on price and market share per firm reduce profits in the region where firms are more numerous. We call this "*intra-regional competition effects*". They play against concentration because they create incentives for firms to locate in the region where they are less numerous. Propositions 1 and 2 support this point.

PROPOSITION 1: In the region where more firms are established:
(i) the price is lower,
(ii) the market share of a firm in its local market is lower,
(iii) the market share of a firm in its export market is higher.
$n_i > n_j \Rightarrow p_i < p_j$, $\frac{q_{ii}}{Q_i} < \frac{q_{jj}}{Q_j}$ and $\frac{q_{ij}}{Q_j} > \frac{q_{ji}}{Q_i}$.

Proof: (i) $p_i - p_j = \frac{(n_j-n_i)t}{n_1+n_2-1}$. (ii) $\frac{q_{ii}}{Q_i} < \frac{q_{jj}}{Q_j} \Leftrightarrow \frac{n_i q_{ii}+n_j q_{ji}}{q_{ii}} > \frac{n_i q_{ij}+n_j q_{jj}}{q_{jj}} \Leftrightarrow \frac{t\frac{w}{g}(n_i-n_j)(n_1+n_2-1)}{\left(\frac{w}{g}+n_1 t\right)\left(\frac{w}{g}+n_2 t\right)}$. (iii) $\frac{q_{ij}}{Q_j} < \frac{q_{ji}}{Q_i} \Leftrightarrow \frac{n_i q_{ij}+n_j q_{jj}}{q_{ij}} > \frac{n_i q_{ii}+n_j q_{ji}}{q_{ji}} \Leftrightarrow \frac{t\left(\frac{w}{g}+t\right)(n_i-n_j)(n_1+n_2-1)}{\left(\frac{w}{g}+t-n_1 t\right)\left(\frac{w}{g}+t-n_2 t\right)} > 0$. The denominator is positive if both types of firms produce. □

Then, if demands were equal in both regions, proposition 1 implies that the profit on local sales would be lower in the region where firms are more numerous. The contrary happens in export market, but proposition 2 shows that the effect on local profit dominates:

PROPOSITION 2: If demands are identical in both regions, profits are higher in the region where less firms are established.

Proof: Assume $Q = Q_i = Q_j$ and let $r_i = \frac{q_{ii}}{q_{ji}} = \frac{\left(\frac{w}{g}+n_j t\right)}{\left(\frac{w}{g}+t-n_i t\right)}$, $q_{ii} = \frac{Q}{n_i+\frac{n_j}{r_i}}$ and $q_{ij} = \frac{q_{ii}}{r_i}$. It is easy to compute that: $\pi_i - \pi_j = -\frac{t^2\left(1+\frac{w}{g}+t\right)(n_i-n_j)(n_1+n_2-1)}{\left(\left(\frac{w}{g}+t\right)n_1+n_2\frac{w}{g}\right)\left(\left(\frac{w}{g}+t\right)n_2+n_1\frac{w}{g}\right)}Q$. □

Second, proposition 3 shows that the presence of transportation costs gives an advantage to the local firms on their local market.

PROPOSITION 3: (i) The marginal profit is always higher on local sales than on exports.
(ii) A firm located in region i always produces more for the local market, market i, than a firm located in region j.
(iii) The ratio $\frac{q_{ii}}{q_{ji}}$ is higher in the region where more firms are located and increases with the number of firms (n_i or n_j).
$n_i > n_j \Rightarrow p_i - \frac{w_i}{g_i} > \left(p_j - \frac{w_i}{g_i} - t\right)$, $q_{ii} > q_{ji}$ and $\frac{q_{ii}}{q_{ji}} > \frac{q_{jj}}{q_{ij}}$.

Proof: (i) $p_i - \frac{w_i}{g_i} - \left(p_j - \frac{w_i}{g_i} - t\right) = \frac{(2n_j-1)t}{n_1+n_2-1}$. (ii) $\frac{q_{ii}}{q_{ji}} = \frac{\frac{w_i}{g_i}+n_j t}{\frac{w_j}{g_j}+t-n_i t} > 1$.
(iii) $\frac{q_{ii}}{q_{ji}} > \frac{q_{jj}}{q_{ij}} \Leftrightarrow \frac{\frac{w_i}{g_i}+n_j t}{\frac{w_j}{g_j}+t-n_i t} > \frac{\frac{w_j}{g_j}+n_i t}{\frac{w_i}{g_i}+t-n_j t} \Leftrightarrow t^2(n_i-n_j)(n_1+n_2-1) > 0$. □

Proposition 3 shows that the advantage on quantities increases with the number of firms and is greater in the region where more firms are set up. Transportation costs act as a trade barrier whose effect is higher, the higher the number of firms and which is higher in the market where more firms are established. Local firms have a cost advantage in the local market and strategic interactions arising in Cournot competition make them individually produce more for this market than importing firms and this, the more numerous they are. We shall refer to this as "*inter-regional competition effects*". They can induce agglomeration if regional demands are not equal: firms have incentives to locate close to the largest demand, which may counterbalance the direct competition effects.

Now, in the model, and because regional incomes are endogenous, regional demands tend to be higher in the region where more firms are set up. The first effect is the price effect: because the price is lower in this region (see proposition 1), demand tends to be higher there. *Aggregate market share effects* reinforce this effect. They are illustrated by propositions 4 and 5.

PROPOSITION 4: The aggregate penetration rate in region i, $\frac{n_j q_{ji}}{n_i q_{ii}}$, is lower in the region where firms are less numerous.
$n_i > n_j \Rightarrow \frac{n_j q_{ji}}{n_i q_{ii}} < \frac{n_i q_{ij}}{n_j q_{jj}}$.

Proof: $n_i > n_j \Rightarrow \frac{n_j q_{ji}}{n_i q_{ii}} < \frac{q_{ji}}{q_{ii}}$ and $\frac{q_{ij}}{q_{jj}} < \frac{n_i q_{ij}}{n_j q_{jj}}$. By proposition 3, $\frac{q_{ji}}{q_{ii}} < \frac{q_{ij}}{q_{jj}}$. □

PROPOSITION 5: In the region where more firms are located:
(i) The aggregate market share of local firms in their local market is higher.
(ii) The aggregate market share of firms in their export market is higher.
$n_i > n_j \Rightarrow \frac{n_i q_{ii}}{Q_i} > \frac{n_j q_{jj}}{Q_j}$ and $\frac{n_i q_{ij}}{Q_j} > \frac{n_j q_{ji}}{Q_i}$.

Proof: (i) $\frac{n_i q_{ii}}{Q_i} > \frac{n_j q_{jj}}{Q_j} \Leftrightarrow \frac{n_j q_{ji}}{n_i q_{ii} + n_j q_{ji}} < \frac{n_i q_{ij}}{n_j q_{jj} + n_i q_{ij}} \Leftrightarrow \frac{n_j q_{ji}}{n_i q_{ii}} < \frac{n_i q_{ij}}{n_j q_{jj}}$, true by proposition 4. (ii) $\frac{n_i q_{ij}}{Q_j} > \frac{n_j q_{ji}}{Q_i} \Leftrightarrow \frac{Q_j - n_j q_{jj}}{Q_j} > \frac{Q_i - n_i q_{ii}}{Q_i} \Leftrightarrow \frac{n_i q_{ii}}{Q_i} > \frac{n_j q_{jj}}{Q_j}$, true by (i). □

Then, these aggregate market shares effects can be interpreted as *crowding out effects*. When more firms are set up in a region, they not only exclude more importing firms from their local market, but they are also less excluded from their export market. Now, regional income is the sum of farmers' income, which is the same in both regions, of total workers' income, which is higher in the region where aggregate production is higher, and of aggregate profits. If regional incomes were identical, the total production of firms located in the region where they are more numerous would be higher by proposition 5, which would increase the regional income in this region. If the regional income is higher in this region, this effect is reinforced. Then, inter-regional competition combined with crowding out effects shows that Cournot competition playing on endogenous regional incomes creates a *cumulative agglomeration force*.

3.2. Comparison of the Profits

Our purpose is to study the difference in profits per firm between two regions which differ by the number of firms. The analytical expression of this difference is given in appendix 2. We rely on simulations to assess which of the previously described effects dominates. In what follows, we will refer to the results observed on simulations as Results. The values of the parameters used for the figures are given in appendix 3, but the results presented emerge for all simulations we performed.

Regarding the profit on local sales, the direct price and firm market share effects lower the profit in the region where more firms are set up and then play against concentration. They dominate when the number of firms is high. The inter-regional competition and crowding out effects favor concentration and dominate when firms are less numerous. Regarding export profits, these effects are reversed, but the local profit accounts more on total profit than the export profit (see propositions 3). Then, total profits can be higher in the region where more firms are located when the number of firms is low. When the number of firms is high, assuming that the zero-profit constraint is still non-binding, firms are excluded from their export market. The export profit is equal to zero and the local profit tends to zero: clearly, when the number of firms is high, the total profit is lower in the region where more firms are established.

RESULT 1: If the number of firms is small enough, profits are higher in the region where more firms are established.

More precisely, there exists a function $\varphi(n_1, n_2)$ increasing in both arguments such that:

$$\text{if } \varphi(n_1, n_2) < 0, \; n_i > n_j \Longrightarrow \pi_i > \pi_j,$$
$$\text{if } \varphi(n_1, n_2) > 0 \; n_i > n_j \Longrightarrow \pi_i < \pi_j.$$

Figure 2, where $prof_i$ is the profit of a firm located in region i, illustrates these results. Assuming that the number of firms located in region 2 is fixed and that initially the number of firms in region 1 is identical (equal to 12 in figure 2), profits are identical in both regions. From this situation, if n_1 increases, profits become higher in region 1 although firms are more numerous in this region. If n_1 becomes very high, profits become lower in region 1.

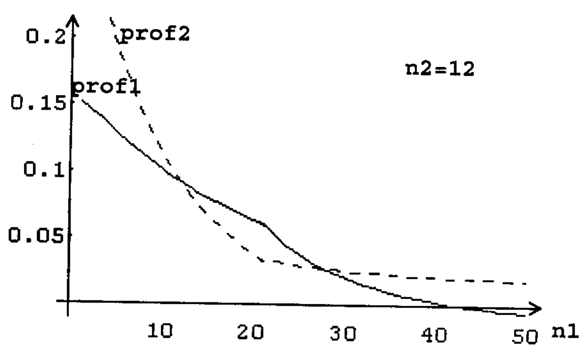

FIGURE 2

Variation of profits with n_2 fixed.

4 Dynamics of Industrialization: A Static Comparative Approach

In the previous part, we have studied the short-run equilibrium: we have considered that the number of firms was exogenously given. In this part, we are interested in the long-run equilibrium and, more precisely, we want to determine if this equilibrium is symmetric or not in the number of firms. When there is free entry, do the new firms agglomerate in only one region or do they symmetrically locate in both regions? Although we are mostly going to comment the long-run equilibria and the implications of the zero-profit constraints, we may have a "flavor" of what could be the transitional dynamics under simplifying assumptions, which, we think, could be generalized. Starting from a given number of firms located in each region, we assume that there is a constant flow of potential entrants that can locate in either region. We assume that these firms are myopic, that is, they only consider the difference in profits between regions at the time. They do not anticipate any future evolution of their profits and, once set up, they do not change their location. We are going to plot the industrialization paths and the long-run equilibrium.

We first plot in the space (n_1, n_2) the set of points where profits are equal in both regions. We also plot on this diagram the zero-profit and the full-employment constraints. We obtain figure 3.

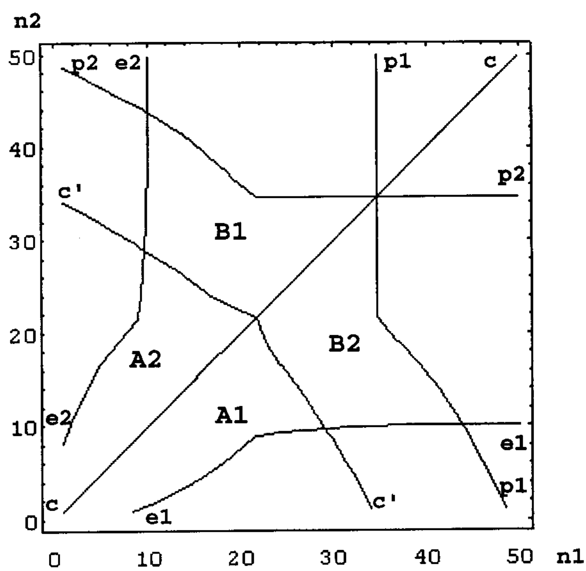

FIGURE 3

Difference of profits.

cc and c' are the sets where profits are equal in both regions. The $e1e1$ and $e2e2$ curves are the full-employment constraints for region 1 and region 2, respectively. $p1p1$ and $p2p2$ are the zero-profit constraints for each region. This means that the only feasible points (n_1, n_2), where profits are positive and employment is not saturated, belongs to areas A_1, A_2, B_1, and

B_2. Result 1 is illustrated by the fact that in areas A_1 and B_1 profits are higher in region 1, whereas it is the contrary in areas A_2 and B_2.

In figure 4, if the initial point is in A_1, where $n_1 > n_2$ and $\pi_1 > \pi_2$, new entrants choose to locate in region 1, although more firms are already located in this region: the path is horizontal and industrial agglomeration occurs. If the path starts at $a1$, it reaches the profit equality constraint at $a2$. From this point, since profits now become higher in region 2, firms locate in region 2 and the path becomes vertical, up to $a3$, which corresponds to an industrial convergence of the regions. Since profits are now identical, the industrialization path follows the diagonal. Firms locate alternatively in both regions and the equilibrium is reached in $a4$, where profits are zero: no more firms can enter and the industrialization process stops. Then, along the path $a1a4$, we first have a *divergence phase* due to the inter-regional competition and to the demand effects (see propositions 3, 4 and 5), during which firms locate in the region where they are more numerous. But this phase is followed by a *convergence phase,* due to the intra-regional competition (see proposition 1), during which firms locate in the region where they are less numerous. In this case, *the long-run equilibrium is symmetric* and the regions are equally developed.

The path $b1b4$ represents another type of industrialization. The full-employment constraint becomes binding at $b2$. From this point although all firms would prefer to locate in region 1, they cannot, because there is no more free labor available. Thus, some firms are obliged to locate in region 2, which relaxes the full-employment constraint in region 1, because the total production of firms 1 decreases (path $b2b3$). From $b3$, the path is

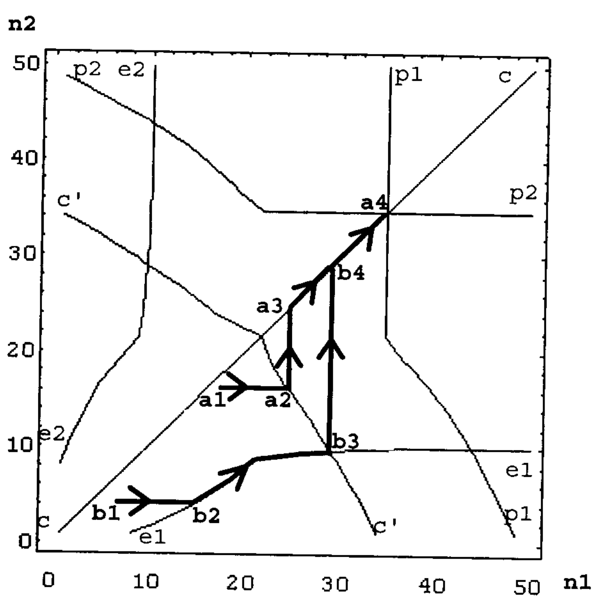

FIGURE 4

Industrialization paths.

comparable to the previous one. In this case, during the divergence phase, a return force to convergence, that can be viewed as a *congestion force*, appears. This assumes that firms perceive the employment constraint and relies on the fact that firms are myopic, wages are rigid and that there is no migration between regions. Clearly, this saturation of the full-employment constraint should induce wages to increase, which would reduce marginal profits in region 1. It would also induce a positive income effect in this region. We believe that it would not change the dynamics and that the succession of the two phases, divergence then convergence, is robust.

In both previous cases, if the initial point is in B_2, the divergence phase does not exist and the industrialization is from its outset in a convergence phase.

Hence, the model explains how concentration and agglomeration may appear because of strategic interactions effects in a framework where demand is endogenous. It also shows that this process is interrupted when the degree of competition becomes too high or when the labor market is saturated.

4.1. Role of Fixed Costs

Fixed costs, which reflect economies of scale, determine the maximum number of firms that can enter with non-negative profits. As long as fixed costs are equal in both regions, they do not directly influence the difference in profits. But, in figure 4, increasing the fixed costs pushes down the zero-profit conditions. Starting from the previous case, a slight increase in fixed costs would not change qualitatively the industrialization paths but lower the long-run number of firms. However, if fixed costs are high enough, the zero-profit constraints can be binding during the divergence phase and in this case the long-run equilibrium is asymmetric.

RESULT 2: If fixed costs are low, the free-entry equilibrium is symmetric in the number of firms, whatever the initial distribution of firms. If fixed costs are high, the equilibrium number of firms is higher in the region where more firms are initially located.

This result is illustrated in figures 5 and 6, where fixed costs are respectively one and a half times and three times higher than in the first simulation. In figure 5, we can observe a phenomenon that we call *over-industrialization* which appears during the convergence phase: some firms have to leave region 1 during this phase (phase $c3c4$), because too many of them locate in region 1 during the divergence phase. This effect may however disappear with far sighted firms and entry costs.

Thus, the higher the economies of scale, the more reinforced the agglomeration effects and the higher the probability of reaching an asymmetric equilibrium. Moreover, we also observe that the initial condition determines in which region industry is concentrated in the long-run: in this sense, we say that "*history matters*". When economies of scale are high, the circular causality due to the externality of demand (see propositions 4 and 5), locks-in firms within the region where they are initially more numerous.

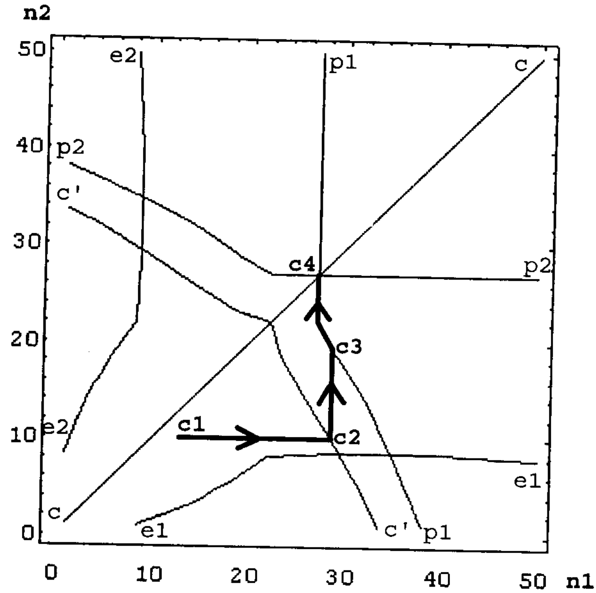

FIGURE 5

Medium fixed costs.

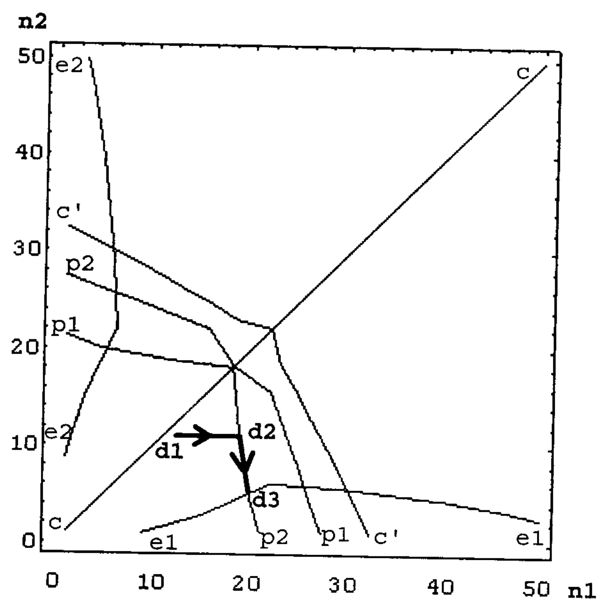

FIGURE 6

High fixed costs.

4.2. Impact of Transportation Costs

Factor localization models would not make any sense without transportation costs. The basic idea developed in the recent models of economic geography is that the higher the transportation costs, the less concentrated the economy. Here, high transportation costs means that firms are heavily disadvantaged by strategic effects in their export market. Even if demand is lower in a region, it is profitable for some firms to locate in this region because intra-regional competition dominates and is lower in the region where firms are less numerous. Industry is then equitably distributed between regions. On the contrary, if transportation costs are low, it is profitable to locate close to the highest demand, because horizontal differentiation is not very important, losses due to intra-regional competition are low, whereas inter-regional competition and crowding out effects dominate. In this case, industry is concentrated in the region where more firms are initially set up.

RESULT 3: If transportation costs are high, the free-entry equilibrium is symmetric in the number of firms. If they are low, the equilibrium number of firms is higher in the region where more firms are initially established.

In figures 7 and 8, when transportation costs are reduced, the line $c'c'$ shifts to the north-east, which reduces the convergence phase. If transportation costs are very low, the long-run equilibrium is asymmetric and the initial conditions determine the more developed region.

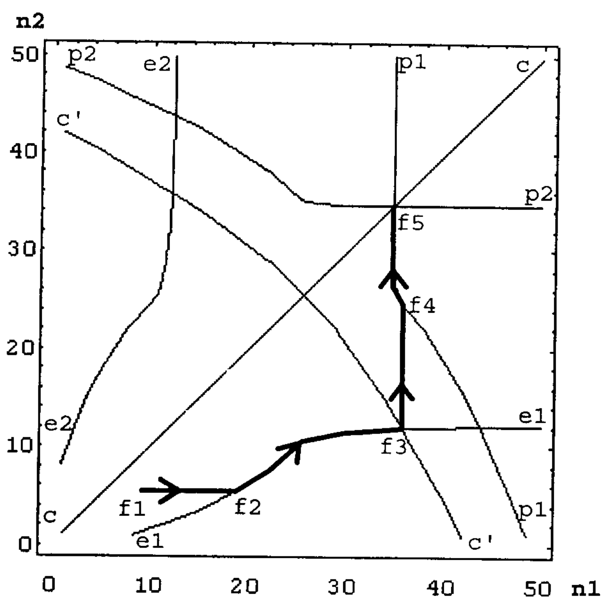

FIGURE 7

Medium transportation costs.

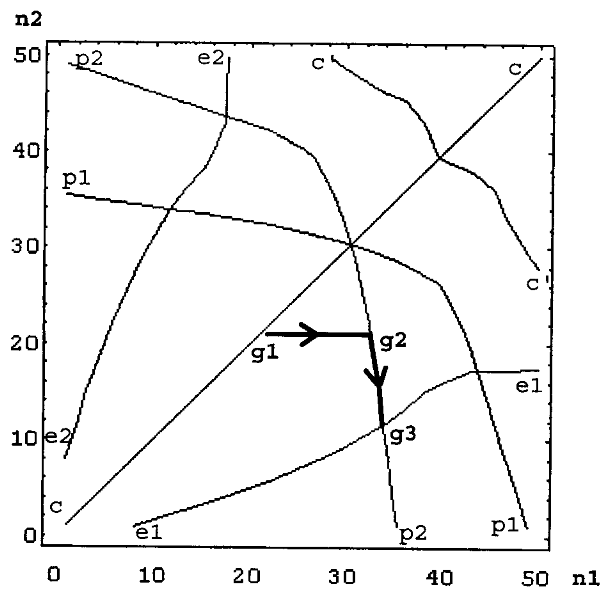

FIGURE 8

Low transportation costs.

5 On the Role of Asymmetries between Regions

The regional conditions of production are not necessarily identical in both regions: marginal or fixed costs, productivity, size of the population of farmers may differ, which influence the industrialization paths and the equilibria. We address this issue in this section.

5.1. Marginal Costs and Productivities

If there exists a huge asymmetry between regions so that firms i are more competitive in both markets [3], i.e. $\frac{w_i}{g_i} + t < \frac{w_j}{g_j}$, case of area A_i in figure 1, the marginal profit of firms i is higher as well on local sales as on exports. All strategic effects play in their favor, which induces them to produce more in both markets. When the number of firms increases, firms j are excluded first from their export market, second from their local market. Profits are clearly always higher in region i, where all firms locate as long as the labor market is not saturated. Then, a high asymmetry in effective marginal cost always implies agglomeration.

3. Either because wages are low or productivity high.

PROPOSITION 6: If $\frac{w_i}{g_i} + t < \frac{w_j}{g_j}$, in the free-entry equilibrium, the number of firms is greater in region i, whatever the initial number of firms.

When the asymmetry is lower, *ie* $\frac{w_i}{g_i} < \frac{w_j}{g_j}$ but $\frac{w_i}{g_i} + t > \frac{w_j}{g_j}$, firms cannot be excluded from their local market. But the price effects disadvantage less firms i than firms j and inter-regional competition is also reinforced in market i and weakened in market j (see the proof of proposition 3). Agglomeration is then reinforced, in favor of region i.

RESULT 4: If $\frac{w_i}{g_i} < \frac{w_j}{g_j}$ and $\frac{w_i}{g_i} + t > \frac{w_j}{g_j}$, the long-run equilibrium number of firms i is greater or equal than the number of firms j, even if, in some cases, more firms are initially located in region j.

On the simulations, the curves change as presented in figure 9.

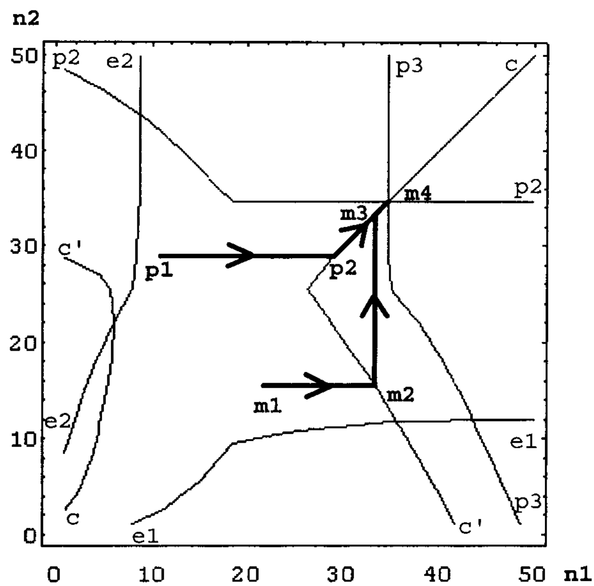

FIGURE 9

Asymmetry in effective marginal cost : $\frac{w_1}{g_1} < \frac{w_2}{g_2}$.

5.2. **Fixed Costs**

Asymmetries in fixed costs first directly affect the difference in profits, in favor of the low fixed costs region: the maximum number of firms that can locate in this region is higher. It also has an indirect effect on demand, because the aggregate fixed costs are deduced from demand. We have result 5.

RESULT 5: If fixed costs are lower in region i, the equilibrium number of firms i is greater than the number of firms j, even if, in some cases, more firms are initially set up in region j.

Simulations are comparable to the previous one.

5.3. **Size of the Population**

If the number of farmers does not differ between regions, a difference in the size of regional populations only affects the possible saturation of the labor market. In contrast, a difference in the size of the population of farmers, which are immobile, affects profits through a direct demand effect. It reinforces the agglomeration effects in favor of the region with the largest population of farmers, because inter-regional competition plays on a higher demand.

RESULT 6: If the population of farmers is higher in region i, in long-run equilibrium, the number of firms i is greater than the number of firms j, even if, in some cases, more firms are initially located in region j.

Thus, as we could expect, asymmetries in the regional conditions of production are a strong agglomeration force which reinforce the inter-regional competition effects. Even if transportation costs are high or economies of scale are low, more firms are located in the long run in the region which has the advantage, even if, in some cases, it is not the initially more developed.

6 Conclusion

Our analysis shows how strategic interactions in the manner of Cournot may influence the location of firms and the industrialization process. The classical trade-off between transportation costs and economies of scale emerges but works in a way different from what we observe in monopolistic competition models *à la* Chamberlin. In addition, the role of strategic interactions is reinforced by regional asymmetries in costs and in the population size.

Many other effects influencing location are not present in this model. For instance, we take productivity and scale economies as fixed parameters. Clearly, the size of the industrial sector has an influence on these parameters that should be endogenous. For instance, a link with endogenous growth theory should be made in order to take into account externalities arising from the accumulation of knowledge. The bigger the industrial sector, the higher the face-to-face communications between firms and the higher the inter-firms labor movements. This necessarily increases the external economies in agglomerated economies. AGHION and HOWITT [1992], GROSSMAN and HELPMAN [1991] have modelled the influence of R&D activities on economic growth. Using similar models in a spatial context could also shed new light on the industrialization process and constitute a future line of research. A first approach is given by ENGELMAN and WALZ [1995]. These authors also try to include some features linked with the segmentation of the labor markets. More precisely, we think that the migration behaviors differ greatly among workers, depending for instance on their skills, and that local labor markets of specialized workers emerge. The interactions between firms on these labor markets influence their location and should also be considered.

1. Areas of production

The marginal profits are given by:

$$p_i - \frac{w_i}{g_i} = \frac{n_j\left(\frac{w_j}{g_j} + t\right) - (n_j - 1)\frac{w_i}{g_i}}{n_1 + n_2 - 1} > 0$$

$$\Leftrightarrow n_j < \operatorname{Max} n_{ii} = \frac{\frac{w_i}{g_i}}{\frac{w_i}{g_i} - \left(\frac{w_j}{g_j} + t\right)},$$

and :

$$p_j - \frac{w_i}{g_i} - t = \frac{n_j\frac{w_j}{g_j} - (n_j - 1)\left(\frac{w_i}{g_i} + t\right)}{n_1 + n_2 - 1} > 0$$

$$\Leftrightarrow n_j < \operatorname{Max} n_{ij} = \frac{\frac{w_i}{g_i} + t}{\frac{w_i}{g_i} + t - \frac{w_j}{g_j}}$$

$\operatorname{Max} n_{ij}$ exists and is positive if $\frac{w_i}{g_i} + t > \frac{w_j}{g_j}$ and $\operatorname{Max} n_{ii}$ exists and is positive if $\frac{w_i}{g_i} > \frac{w_j}{g_j} + t$.
Moreover,

$$\operatorname{Max} n_{ii} > \operatorname{Max} n_{ij}.$$

On figure 1, in area B, $\begin{cases} q_{ii} > 0 \\ q_{jj} > 0 \end{cases}$ whatever the number of firms and $\begin{cases} q_{ij} > 0 \Leftrightarrow n_j < \operatorname{Max} n_{ij} \\ q_{ji} > 0 \Leftrightarrow n_i < \operatorname{Max} n_{ji} \end{cases}$.

In area A_i, $\begin{cases} q_{jj} > 0 \\ q_{ji} > 0 \end{cases}$ whatever the number of firms and $\begin{cases} q_{ij} > 0 \Leftrightarrow n_j < \operatorname{Max} n_{ij} \\ q_{ii} > 0 \Leftrightarrow n_j < \operatorname{Max} n_{ii} \end{cases}$.

2. Prices and quantities

3 cases and their symmetric have to be considered.

CASE 1: $q_{ii} > 0$; $q_{ij} > 0$; $q_{jj} > 0$; $q_{ji} > 0$.

The following computations are given for $\frac{w_1}{g_1} = \frac{w_2}{g_2} = 1$, $La_1 = La_2 = La$ and $f_1 = f_2 = f$.

We denote :

$$\begin{cases} a = n_1 + n_2 - 1 \\ b_i = 1 + n_i t \\ c_i = n_i + n_j(1 + t) \\ d_i = n_i(1 - \mu) + n_j(1 + t) - \mu n_1 n_2 t \end{cases} \quad \text{and} \quad \begin{cases} e_i = n_i(1 - t) + n_j + t \\ k_i = \dfrac{1 + t - n_i t}{1 + n_j t} \\ h_i = La - n_i f \\ m_i = 1 + t - n_i t \end{cases}$$

All these terms are positive.

We completely solve the system (I). This leads to:

$$(I) \Leftrightarrow \begin{cases} p_i = \dfrac{c_i}{a} \\ q_{ii} = \dfrac{\mu a b_j (c_j d_j h_i + \mu n_i e_j m_j h_j)}{c_1 c_2 d_1 d_2 - \mu^2 n_1 n_2 e_1 e_2 m_1 m_2} \\ q_{ji} = k_i q_{ii} \end{cases}$$

The difference in profits is then given by:

$$\pi_i - \pi_j = \frac{\mu a t (n_i - n_j) P(n_i, n_j, \mu, t, f, La)}{c_1 c_2 d_1 d_2 - \mu^2 n_1 n_2 e_1 e_2 m_1 m_2}.$$

The denominator is positive because q_{ii} is positive and $\mu a t(n_i - n_j) > 0 \iff n_i > n_j$. $P(n_i, n_j, \mu, t, f, La)$ is a polynomial function of degree three in n_1, n_2 or t, parametrized by μ, f and La ! Completely developed, it has 57 terms and is very tedious to sign.

CASE 2: $q_{ii} > 0$; $q_{ij} = 0$; $q_{jj} > 0$; $q_{ji} > 0$.

$$\begin{cases} p_i = \dfrac{n_i \frac{w_i}{g_i} + n_j\left(\frac{w_j}{g_j} + t\right)}{n_1 + n_2 - 1} \\ p_j = \dfrac{n_j}{n_j - 1} \dfrac{w_j}{g_j} \\ q_{ii} = \dfrac{\frac{\mu}{p_i}(La_i - n_i f_i)\left(n_j\left(\frac{w_j}{g_j} + t - \frac{w_i}{g_i}\right) + \frac{w_i}{g_i}\right)}{n_i(1-\mu)\left(n_j\left(\frac{w_j}{g_j} + t - \frac{w_i}{g_i}\right) + \frac{w_i}{g_i}\right) + \frac{w_j}{g_j} + t - n_i\left(\frac{w_j}{g_j} + t - \frac{w_i}{g_i}\right)} \\ q_{ij} = 0 \\ q_{ji} = \dfrac{\frac{\mu}{p_i}(La_i - n_i f_i)\left(\frac{w_j}{g_j} + t - n_i\left(\frac{w_j}{g_j} + t - \frac{w_i}{g_i}\right)\right)}{n_i(1-\mu)\left(n_j\left(\frac{w_j}{g_j} + t - \frac{w_i}{g_i}\right) + \frac{w_i}{g_i}\right) + \frac{w_j}{g_j} + t - n_i\left(\frac{w_j}{g_j} + t - \frac{w_i}{g_i}\right)} \\ q_{jj} = \dfrac{\mu}{1-\mu} \dfrac{1}{n_j p_j}(La_j - n_j f_j + n_j(p_i - t) q_{ji}) \end{cases}$$

CASE 3: $q_{ii} = 0$; $q_{ij} = 0$; $q_{jj} > 0$; $q_{ji} > 0$.

$$\begin{cases} p_i = \frac{n_j}{n_j - 1}\left(\frac{w_j}{g_j} + t\right) \\ p_j = \dfrac{n_j}{n_j - 1} \dfrac{w_j}{g_j} \\ q_{ii} = 0 \\ q_{ij} = 0 \\ q_{ji} = \dfrac{\mu L a_i}{n_j p_i} \\ q_{jj} = \dfrac{\mu}{1-\mu} \dfrac{1}{n_j p_j}(La_j - n_j f_j + n_j(p_i - t) q_{ji}) \end{cases}$$

3. Parameters values for the simulations

Benchmark case: $w_i = 1$, $g_i = 1$, $t = 0.05$, $\mu = 0.72$, $L_i = 100$, $La_i = 20$, $f_i = 0.02$

Medium fixed costs: $f_i = 0.03$

High fixed costs: $f_i = 0.06$

Medium transportation costs: $t = 0.04$

Low transportation costs: $t = 0.03$

Asymmetries in effective marginal costs: $\frac{w_1}{g_1} = 0.99$ and $\frac{w_2}{g_2} = 1.01$

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