
Industrial clusters and peripheral areas

José Pedro Pontes

Instituto Superior de Economia e Gestão, Rua Miguel Lupi 20, 1249-078 Lisbon, Portugal;

e-mail: ppontes@iseg.utl.pt

Received 14 January 2003; in revised form 23 April 2003

Abstract. This paper is an appraisal of the economic feasibility of the location of clusters of firms in peripheral areas. In a spatial economy formed by two asymmetric regions, an upstream firm supplies an input to two downstream firms. This economy is modelled as a three-stage noncooperative game. In the first stage, the firms choose locations simultaneously. In the second stage, the upstream firm selects a monopoly price for the downstream firms. In the third stage, the final good firms compete in quantities, taking the input price as given. If it is assumed that each firm is active in each market, the agglomeration of all firms in the large region is always a perfect equilibrium, although it need not be unique. If vertical linkages are intermediate and transport costs are high, there is a dispersed equilibrium with the upstream firm in the small region. If vertical linkages are strong and transport costs are low, a cluster can occur in the small region. In this latter case, regional policy can select the small peripheral region as a location for the industrial cluster.

1 Introduction

This paper addresses the issue of the economic feasibility of the location of industrial clusters in peripheral regions. In order to do this, I deal with the agglomeration of the productive activity in space using a partial equilibrium methodology. There are two conflicting perspectives on this issue.

The first perspective assumes that the clustering of firms takes place in regions with good market access. As Krugman and Venables (1990) pointed out, when transport costs are high, firms are scattered in space in order to serve local customers. If transport costs are low, firms cease to be attracted by local demand and become oriented by global demand. Accordingly, they locate in the central point of the spatial distribution of consumers, that is, in a region with a large market size and central position relative to other regions, where the accessibility to consumers is maximized.

In this paper, this problem will be tackled with reference to a spatial economy consisting of two regions that are asymmetric in size. Differences in size do not matter in themselves but rather in the sense that they determine a different degree of market access for the firms that locate in each region. Therefore, the large region is the central point of the spatial distribution of consumers. The paper builds upon the results of Cournot competition by firms that select locations in a continuous linear space.⁽¹⁾

⁽¹⁾ Although in theory it would be possible to deal with this problem using Bertrand competition in the consumer good market, such a solution would not be suitable for research into the sources of the agglomeration of firms. As was acknowledged by D'Aspremont et al (1979), Bertrand pricing in spatial models leads firms to differentiate locations. In the Hotelling model, the agglomeration breaks down in the case of linear transport costs on account of the nonexistence of a Nash price equilibrium for the close location of firms. If the existence of a price equilibrium is reestablished through the assumption of quadratic transport costs, the Nash equilibrium of location entails maximum differentiation. It is, of course, possible to superimpose the centrifugal forces of Bertrand pricing and the centripetal forces of a spatial externality (a 'spillover'). However, in this case, agglomeration is either only a limiting case (as in Mai and Peng, 1999), or the consequence of special assumptions [multiplant firms and spillovers internal to the firm in Gersbach and Schmutzler (1999)]. For these reasons, Cournot competition appeared to be a natural path for analyzing agglomeration with intermediate goods.

Anderson and Neven (1991) and Gupta et al (1997) concluded that, in this case, there is agglomeration of firms in the central point of the spatial distribution of consumers provided that the unit transport cost is low enough in relation to the density of consumers at that point.

Combes (1997) provided an intuitive rationale for this result. Firms tend to locate in the central point of the spatial distribution of consumers, which is the point that maximizes their accessibility to consumers. However, by doing this, they engage in 'intra-regional' competition for local customers with neighbouring firms, thus decreasing each firm's market share and the market price in the neighbouring region. The severity of this competition is higher the lower the density of consumers in the central point.

Therefore, if transport costs are high, some firms increase their profits by moving to peripheral locations. They relax intra-regional competition for consumers in the central area, while 'inter-regional' competition, where a firm competes for consumers who are distant from its location but close to that of its competitor is not meaningful on account of the barrier of high transport costs. However, if transport costs are low, relocation to the periphery is not profitable, because the relaxation of intra-regional competition is offset by inter-regional competition. Hence, firms prefer to agglomerate at the point that maximizes accessibility to all consumers.

Krugman (1991) has shown that, in a general equilibrium framework, the interaction of the location of those firms that target global demand with labour mobility deepens the agglomeration of the increasing returns productive activity. Empirical evidence shows that most industrial clusters occur in densely populated areas with a high degree of market access (see, for instance, *The Economist* 1995). The financial industry is concentrated in the largest metropolises, such as New York, London, and Tokyo. If the agglomeration is not based in a large city but takes the shape of an urban sprawl (as in the case of the computer industry in Silicon Valley, California or Route 128 in Massachusetts) or in a series of small cities (as in the case of the textile and fashion industry clustered in the valley of the River Po in Northern Italy), the agglomeration is nevertheless based in a core region endowed with a high degree of accessibility to consumers.

However, this is just one part of the picture. In a second perspective, the location of firms becomes more complex if unit production costs vary in space, as dealt with by Mayer (2000). This can happen, for instance, if each firm uses an input that is available at a single source (a port) and it bears the transport cost of the input between the source and its location. In this case, when firms select their locations, they face a trade-off between the point that minimizes the unit production cost (the source of the input) and the point that maximizes accessibility to consumers (the central point of the market). Mayer (2000) concluded that the pull of the input source is larger than the pull of the central point because, whereas a shift from the former entails, a rise in the unit production cost to *all* consumers, a shift from the latter increases the transport costs to *some* consumers but decreases them for *some* subset of consumers.

In this paper, I deal with this market situation, but it is assumed that the location of the input source is endogenous. This is chosen by an upstream firm simultaneously with the location of the production of the consumer good by downstream firms. More precisely, in this model, an upstream firm supplies an intermediate good to two downstream firms which then transport the input, process it, and deliver the final good to consumers. The upstream firm selects a monopoly price for the intermediate good. Downstream firms take this price as given and compete in quantities (à la Cournot) in the market of each region.

The model generalizes that of Hwang and Mai (1989), who also simultaneously determined the locations of an upstream and a downstream firm. However, they dealt

with a successive monopoly, whereas this model entails a duopoly in the downstream stage. Furthermore, they assumed a single market point whereas this model includes two asymmetric regions.

The exchange of intermediate goods is simply one form of technological interaction between firms. As Marshall (1920) has shown, there are at least two other important forms of interaction: (1) labour turnover, that is, a firm trains a worker who is hired by a neighbouring firm; (2) spillovers, that is, informal transfers of technical knowledge between firms. Each kind of technological interaction is made easier by the proximity of firms.

It will be assumed that all kinds of technological interactions are represented by the exchange of intermediate goods [see, among others, Gersbach and Schmutzler (1999) and Mai and Peng (1999) who deal with the role of technological spillovers in the growth of industrial clusters]. As Venables (1996) observed, the savings made in the transport costs of intermediate goods encourage upstream and downstream firms to locate together in clusters.

The agglomeration of firms tied together by the exchange of intermediate goods does not necessarily occur in a core region. The location of firms is not influenced by the accessibility of final consumers, but rather by the savings in unit production costs that arise from proximity to the input suppliers. Any location of the firm that fulfils the requirement of proximity to other plants with which it maintains input–output relations is an advantageous location. As Fujita (1981) has remarked, if the choice of locations by vertically related firms is modelled as a noncooperative game, the solution will entail a multiplicity of equilibria. Each location in which suppliers and buyers of inputs stay close to one another is a Nash equilibrium. Under these conditions, regional policy can select the spatial equilibrium and shift the agglomeration towards a peripheral area.

There are examples of industrial clusters located in peripheral areas. For instance, the Portuguese economy is organized around the metropolitan areas of Lisbon and Oporto. Nevertheless, some important industrial clusters are placed outside these major areas.

However, there is a steady trend towards a fall of transport and communication costs and a process of trade liberalization both inside regional integration areas and across them. These trends [usually described as ‘globalization’ (see Baldwin and Robert-Nicoud, 2000)] decrease the relative weight of the transport cost of intermediate goods. This raises the question whether industrial clusters located in peripheral areas can survive reductions in the factor that brought them about. I will try to answer this question in the paper.

The paper is organized as follows. In section 2, the assumptions of the model will be described. In section 3, the interaction of the firms is modelled by means of a three-stage game. In section 4, the noncooperative game is solved. Section 5 draws the main conclusions.

2 Assumptions of the model

We assume an economy that obeys the following assumptions:

1. There are two asymmetric regions labelled A and B. The population in A is larger than the population in B: $n_a > n_b$.
2. There are two downstream firms, labelled 1 and 2, which produce a homogeneous consumer good, and an upstream firm, labelled firm 3, that produces and sells an intermediate good to the downstream firms. Each firm runs a single plant and always stays in the market. The upstream firm has a constant unit production cost c_k . The downstream firms have constant unit production costs c . Without mentioning fixed

costs, it is implicitly assumed that they are neither too low (because the firms would then become multiplant) nor too high (because the firms would then exit the market). The assumption that economies of scale are higher in the upstream industry than in the downstream industry also forms a central part of the argument without being openly stated.

3. As a monopolist the upstream firm chooses the profit-maximizing fob (free on board) mill price k for the intermediate good. The downstream firms take this price as given and compete in quantities à la Cournot in the market of the consumer good. Let q_{1a} be the quantity that firm 1 supplies in market A and q_{1b} the quantity supplied in region B. Let q_{2a} be the quantity that firm 2 supplies in region A and q_{2b} the quantity supplied in region B.

4. Downstream firms use the intermediate good in fixed proportions with the final good: α units are required to produce 1 unit of output.

5. Transport costs per unit of distance per unit of product are given by t for the consumer good and by t_k for the intermediate good. Transport costs of both the input and the final good change in proportion to one another. The transport cost of 1 unit of consumer good exceeds the transport cost of the input that is required to produce it: $t > \alpha t_k$.

6. The distance function between two locations x_i, x_j is given by

$$d(x_i, x_j) = \begin{cases} 0, & \text{if } x_i = x_j, \\ 1, & \text{if } x_i \neq x_j. \end{cases} \quad (1)$$

7. The downstream firms transport the input, process it, and deliver the final good to the consumers.

8. Each consumer has an inverse individual demand curve $p = g - fq$, where p is the full (delivered) price, q is individual consumption, and g and f are positive constants.

3 The structure of the game

Following Fujita and Thisse (1993), the working of this economy is modelled through a three-stage game. In the first stage, upstream firm 3 and downstream firms 1 and 2 simultaneously choose locations x_3, x_1, x_2 in $\{A, B\}$. In the second stage, as a monopolist the upstream firm 3 selects the fob mill price k for the intermediate good. In the third stage, downstream firms take k as given. They compete à la Cournot and choose quantities $q_{1a}, q_{1b}, q_{2a}, q_{2b}$ to supply in each market. The equilibrium concept is subgame perfect equilibrium and can be found by means of backward induction.

In the third stage of the game, given the locations of the firms x_1, x_2, x_3 and the price of the intermediate good k , downstream firms have the following profit functions.

$$\begin{aligned} \pi_1(q_{1a}, q_{1b}, q_{2a}, q_{2b}) &= \{p_a - c - td(x_1, A) - \alpha[k + t_k d(x_3, x_1)]\}q_{1a} \\ &\quad + \{p_b - c - td(x_1, B) - \alpha[k + t_k d(x_3, x_1)]\}q_{1b}, \\ \pi_2(q_{1a}, q_{1b}, q_{2a}, q_{2b}) &= \{p_a - c - td(x_2, A) - \alpha[k + t_k d(x_3, x_2)]\}q_{2a} \\ &\quad + \{p_b - c - td(x_2, B) - \alpha[k + t_k d(x_3, x_2)]\}q_{2b}, \end{aligned} \quad (2)$$

where

$$\begin{aligned} p_a &= g - f \left(\frac{q_{1a} + q_{2a}}{n_a} \right), \\ p_b &= g - f \left(\frac{q_{1b} + q_{2b}}{n_b} \right). \end{aligned} \quad (3)$$

Using standard procedures, it is easy to derive Nash–Cournot quantities separately for each market contingent on x_1, x_2, x_3, k :

$$q_{1a}^*(x_1, x_2, x_3, k), q_{1b}^*(x_1, x_2, x_3, k), q_{2a}^*(x_1, x_2, x_3, k), q_{2b}^*(x_1, x_2, x_3, k). \tag{4}$$

See detailed expressions for equation (4) in appendix A.

In the second stage of the game, the upstream firm maximizes the following profit function in relation to the price k of the intermediate good:

$$\pi_3(k|x_1, x_2, x_3) = (k - c_k) \alpha [q_{1a}^*(x_1, x_2, x_3, k) + q_{1b}^*(x_1, x_2, x_3, k) + q_{2a}^*(x_1, x_2, x_3, k) + q_{2b}^*(x_1, x_2, x_3, k)]. \tag{5}$$

Let

$$k^*(x_1, x_2, x_3) = \operatorname{argmax} \pi_3(k|x_1, x_2, x_3). \tag{6}$$

In the first stage of the game, by substituting $q_{1a}^*(x_1, x_2, x_3, k)$, $q_{1b}^*(x_1, x_2, x_3, k)$, $q_{2a}^*(x_1, x_2, x_3, k)$, $q_{2b}^*(x_1, x_2, x_3, k)$, and $k^*(x_1, x_2, x_3)$ in the profit functions (2) and (5), we obtain profit functions in terms only of the firms' locations. These are the payoff functions in the first-stage game.

$$\pi_1 = \pi_1(x_1, x_2, x_3), \pi_2 = \pi_2(x_1, x_2, x_3), \pi_3 = \pi_3(x_1, x_2, x_3). \tag{7}$$

Although the third-stage and second-stage games are continuous, the first-stage game is discrete and can be represented by a pair of 2×2 matrices.

$$\left(\begin{array}{cc} & \begin{array}{cc} 2 & \\ & \text{A} & \text{B} \end{array} \\ \begin{array}{cc} 1 & \text{A} \\ & \text{B} \end{array} & \begin{array}{cc} \pi_1, \pi_2, \pi_3 & \pi_1, \pi_2, \pi_3 \\ \pi_1, \pi_2, \pi_3 & \pi_1, \pi_2, \pi_3 \end{array} \\ 3 & \text{A} \end{array} \right), \left(\begin{array}{cc} & \begin{array}{cc} 2 & \\ & \text{A} & \text{B} \end{array} \\ \begin{array}{cc} 1 & \text{A} \\ & \text{B} \end{array} & \begin{array}{cc} \pi_1, \pi_2, \pi_3 & \pi_1, \pi_2, \pi_3 \\ \pi_1, \pi_2, \pi_3 & \pi_1, \pi_2, \pi_3 \end{array} \\ 3 & \text{B} \end{array} \right). \tag{8}$$

Firm 1 selects the row, firm 2 selects the column, and firm 3 selects the matrix. In practical terms, we solve each subgame that is initiated in a cell of the matrices. By solving the third and second stages of the game, it is possible to obtain the values of the profits of firms 1, 2, and 3 in terms of the parameters.

As the first stage of the game is discrete, its tractability depends on there being a limited number of parameters (no more than two). With that purpose, it is assumed that

$$t = t_k. \tag{9}$$

This equality is a simple way of modelling assumption 5, according to which the transport of the intermediate good and the consumer good vary in proportion.

Without loss of generality, the following values are assigned to the parameters:

$$c = c_k = 0, \quad g = f = 1, \quad n_a = 2, \quad n_b = 1. \tag{10}$$

With equality (9), the idea present in assumption 5 that the transport cost of 1 unit of consumer good is higher than the transport cost of the input used to produce it is expressed by the constraint

$$0 < \alpha < 1. \tag{11}$$

It is assumed that transport costs are low enough for each downstream firm to be active in each region, irrespective of the possible asymmetry in transport costs that it

must bear in relation to the other firm.⁽²⁾ As can be concluded below [see equations (B1) and (B2) in appendix B], this is equivalent to imposing the constraint

$$t \leq \frac{2}{7(1+\alpha)}. \quad (12)$$

4 Solution of the game

In a first step, the subgames initiated in each of the cells of matrices (8) are solved. The detailed solutions of each subgame are presented in appendix B. In what follows only the payoffs of the firms in the first-stage game in terms of the parameters α and t are mentioned.

(1) Subgame where $x_1 = x_2 = x_3 = A$

The payoffs in the first stage in terms of the parameter t are

$$\pi_1(A, A, A) = \pi_2(A, A, A) = \frac{1}{12} - \frac{1}{18}t + \frac{1}{12}t^2, \quad (13)$$

$$\pi_3(A, A, A) = \frac{1}{2} - \frac{1}{3}t + \frac{1}{18}t^2. \quad (14)$$

(2) Subgame with $x_1 = B, x_2 = x_3 = A$

The payoffs of the firms in the first-stage game in terms of parameters t and α are

$$\pi_1(B, A, A) = \frac{1}{12} - \frac{1}{4}t - \frac{7}{12}\alpha t + \frac{41}{48}t^2 + \frac{7}{8}\alpha t^2 + \frac{49}{48}\alpha^2 t^2, \quad (15)$$

$$\pi_2(B, A, A) = \frac{1}{12} + \frac{1}{12}t + \frac{5}{12}\alpha t + \frac{11}{16}t^2 + \frac{5}{24}\alpha t^2 + \frac{25}{48}\alpha^2 t^2,$$

$$\pi_3(B, A, A) = \frac{1}{2} - \frac{1}{2}t - \frac{1}{2}\alpha t + \frac{1}{8}t^2 + \frac{1}{4}\alpha t^2 + \frac{1}{8}\alpha^2 t^2. \quad (16)$$

(3) Subgame with $x_1 = x_3 = A, x_2 = B$

This case is symmetric to the previous one. Therefore, we have

$$\pi_1(A, B, A) = \pi_2(B, A, A), \quad (17)$$

$$\pi_2(A, B, A) = \pi_1(B, A, A),$$

$$\pi_3(A, B, A) = \pi_3(B, A, A). \quad (18)$$

(4) Subgame where $x_1 = x_2 = B, x_3 = A$

The payoffs of the firms in terms of α and t in the first-stage game are

$$\pi_1(B, B, A) = \pi_2(B, B, A) = \frac{1}{12} - \frac{1}{9}t - \frac{1}{6}\alpha t + \frac{1}{9}\alpha t^2 + \frac{1}{12}\alpha^2 t^2, \quad (19)$$

$$\pi_3(B, B, A) = \frac{1}{2} - \frac{2}{3}t - \alpha t + \frac{2}{9}t^2 + \frac{2}{3}\alpha t^2 + \frac{1}{2}\alpha^2 t^2. \quad (20)$$

⁽²⁾ This simplifying assumption is common in the literature on spatial Cournot oligopoly—see, among others, Anderson and Neven (1991), Gupta et al (1997), and Mayer (2000).

(5) Subgame where $x_1 = x_2 = A$, $x_3 = B$

The payoffs defined in terms of the parameters t and α of the firms in the first-stage game are

$$\pi_1(A, A, B) = \pi_2(A, A, B) = \frac{1}{12} - \frac{1}{18}t - \frac{1}{6}\alpha t + \frac{1}{12}t^2 + \frac{1}{18}\alpha t^2 + \frac{1}{12}\alpha^2 t^2, \quad (21)$$

$$\pi_3(A, A, B) = \frac{1}{2} - \alpha t - \frac{1}{3}t + \frac{1}{2}\alpha^2 t^2 + \frac{1}{3}\alpha t^2 + \frac{1}{18}t^2. \quad (22)$$

(6) Subgame where $x_1 = x_3 = B$, $x_2 = A$

The payoffs of the firms in terms of the parameters α and t in the first-stage game are

$$\pi_1(B, A, B) = \frac{1}{12} - \frac{1}{4}t + \frac{5}{12}\alpha t + \frac{41}{48}t^2 - \frac{5}{8}\alpha t^2 + \frac{25}{48}\alpha^2 t^2, \quad (23)$$

$$\pi_2(B, A, B) = \frac{1}{12} + \frac{1}{12}t - \frac{7}{12}\alpha t + \frac{11}{16}t^2 - \frac{7}{24}\alpha t^2 + \frac{49}{48}\alpha^2 t^2,$$

$$\pi_3(B, A, B) = \frac{1}{2} - \frac{1}{2}t - \frac{1}{2}\alpha t + \frac{1}{8}t^2 + \frac{1}{4}\alpha t^2 + \frac{1}{8}\alpha^2 t^2. \quad (24)$$

(7) Subgame where $x_1 = A$, $x_2 = x_3 = B$

This case is symmetric to the previous one. Hence

$$\pi_1(A, B, B) = \pi_2(B, A, B), \quad (25)$$

$$\pi_2(A, B, B) = \pi_1(B, A, B),$$

$$\pi_3(A, B, B) = \pi_3(B, A, B). \quad (26)$$

(8) Subgame where $x_1 = x_2 = x_3 = B$

The payoffs of the firms in terms of the parameter t in the first-stage game are

$$\pi_1(B, B, B) = \pi_2(B, B, B) = \frac{1}{12} - \frac{1}{9}t + \frac{1}{9}t^2, \quad (27)$$

$$\pi_3(B, B, B) = \frac{1}{2} - \frac{2}{3}t + \frac{2}{9}t^2. \quad (28)$$

In order to find the solution of the first-stage three-firm game as described by matrices (8), a first step is to assess the structure of best replies by the upstream firm 3. It is clear that the following relation holds:

$$\pi_3(A, A, A) > \pi_3(A, A, B), \quad (29)$$

according to expressions (14) and (22). Furthermore

$$\pi_3(A, B, A) = \pi_3(B, A, A) = \pi_3(A, B, B) = \pi_3(B, A, B) \quad (30)$$

holds according to expressions (17), (16), (26), and (24). Finally,

$$\pi_3(B, B, B) > \pi_3(B, B, A), \quad (31)$$

according to expressions (20) and (28).

The above relations mean that, if both downstream firms locate in the same region, the strict best reply of the input supplier is also to locate in that region. If each downstream firm locates in a different region, the upstream firm is indifferent. The economic rationale behind this best-reply structure is self-evident and does not need any further explanation.

In a second step, we solve the truncated 2×2 games, that is, the games played by the downstream firms, assuming the location of the upstream firm as given. These games are easy to solve because they are symmetric, so that only the payoffs of one player need be considered [see Weibull (1997, chapter 1), for a formal treatment of noncooperative symmetric games].

We begin with the truncated game that follows from setting the upstream firm's location in A. It is clear from expressions (13) and (15) that

$$a_1 = \pi_1(A, A, A) - \pi_1(B, A, A) > 0, \quad (32)$$

for

$$t < \frac{2}{7(1+\alpha)} \wedge 0 < \alpha < 1.$$

On the other hand, from expressions (19), (17), and (15), it is easy to conclude that

$$a_2 = \pi_1(B, B, A) - \pi_1(A, B, A) < 0, \text{ for any values of } \alpha, t. \quad (33)$$

Bearing in mind the symmetry of the truncated game, (A, A) is a unique Nash equilibrium. Indeed, in this game, A is a strictly dominating location strategy for each downstream firm. On the other hand, as expression (29) holds, (A, A, A) is a Nash equilibrium of locations for all the feasible values of the parameters. However, it need not be the only equilibrium.

Computing the Nash equilibrium in the truncated game where firm 3's location is set in region B, it is easy to conclude from expressions (21) and (23) that

$$a_1 = \pi_1(A, A, B) - \pi_1(B, A, B) > 0 \iff t < \frac{28(1-3\alpha)}{63\alpha^2 - 98\alpha + 111}. \quad (34)$$

It is obvious that the denominator of equation (34) is positive for $\alpha \in (0, 1)$. A necessary (although not sufficient) condition that $a_1 > 0$ is $\alpha < \frac{1}{3}$. On the other hand, from expressions (27), (25), and (23), we have

$$a_2 = \pi_1(B, B, B) - \pi_1(A, B, B) > 0 \quad (35)$$

$$\iff t < \frac{28(3\alpha - 1)}{83 - 42\alpha + 147\alpha^2}. \quad (36)$$

It is clear that the denominator of the right-hand side of equation (36) is positive for $\alpha \in (0, 1)$. A necessary (although not sufficient) condition that inequality (36) is fulfilled is that $\alpha > \frac{1}{3}$.

The set of Nash equilibria in pure strategies can therefore be fully characterized in the following way. If

$$\alpha < \frac{1}{3}, \quad \text{and } t < \frac{28(1-3\alpha)}{63\alpha^2 - 98\alpha + 111},$$

then $a_1 > 0$, $a_2 < 0$. Each downstream firm has A as a dominating location strategy in the B-truncated game. However, (A, A, B) is not a Nash equilibrium because of relation (29). The best reply of firm 3 to $x_1 = x_2 = A$ is A rather than B.

If

$$\alpha > \frac{1}{3}, \quad \text{and } t < \frac{28(3\alpha - 1)}{83 - 42\alpha + 147\alpha^2},$$

then $a_1 < 0$, $a_2 > 0$. In this case, B is a dominating location strategy for each downstream firm. (B, B, B) is a Nash equilibrium of locations, as, according to inequality (31), B is a best reply for firm 3 to $x_1 = x_2 = B$.

In the remaining cases, that is, if

$$\alpha < \frac{1}{3}, \quad \text{and } t > \frac{28(1 - 3\alpha)}{63\alpha^2 - 98\alpha + 111},$$

or

$$\alpha > \frac{1}{3}, \quad \text{and } t > \frac{28(3\alpha - 1)}{83 - 42\alpha + 147\alpha^2},$$

then the B-truncated game has two Nash equilibria in pure strategies (A, B) and (B, A).⁽³⁾ Furthermore, according to equation (30), (A, B, B) and (B, A, B) are Nash equilibria in this region, although they are *nonstrict*, because for the upstream firm 3 it is indifferent to locate in A or in B in reply to the choice of different locations by the downstream firms. If the input supplier relocates to A, then the downstream firm located in B also moves to A and the outcome of the game changes to the agglomeration in A.

We can summarize the set of Nash equilibria in pure strategies in the (α, t) parameter in figure 1.

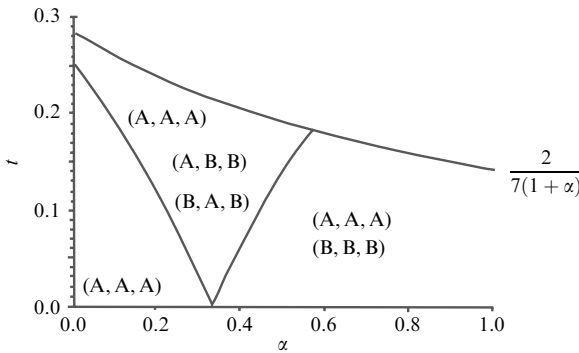


Figure 1. Nash equilibria of location in (α, t) space.

By restricting ourselves to the case where transport costs are low in relation to interindustry complementarities, so that each firm is active in each market for any possible pattern of locations, it is possible to reach several results.

First, the agglomeration of all firms in the large region is a Nash equilibrium of locations for all feasible values of α and t . This outcome follows from the fact that, as transport costs are relatively low, the firms target the global demand and locate in the central point of the spatial distribution of consumers in order to save on delivery costs.

Second, there are regions in the parameters space where this equilibrium is not unique. If transport costs are moderately high (although remaining within the above-defined feasible region) and interindustry complementarities are intermediate, the downstream firms disperse in space in order to supply the local consumers in each region. In this way, they avoid intraregional competition and are protected from interregional competition by the barrier of transport costs. However, this equilibrium implies that the upstream firm is located in the small region, whereas the input supplier is indifferent to locating in the two regions. Hence, the dispersed equilibrium is weak (nonstrict). The upstream firm suffers no loss in shifting to the large region, inducing the downstream firms to cluster once again in that region.

However, if vertical linkages are strong enough and transport costs are low, a cluster can occur in the small region. A low level of transport costs is a necessary

⁽³⁾ It has also a symmetric equilibrium in mixed strategies.

precondition for agglomeration to take place, as high transport costs would lead to dispersion. On the other hand, high vertical linkages mean that the agglomeration of consumer good firms takes place at the point where the transport cost of the input (as a part of the unit production cost) is minimized, that is to say in the peripheral location of the input supplier, rather than in the point with better accessibility to the consumers.

If the region with low vertical linkages and low transport costs is excepted, the location game exhibits multiple equilibria. In the region with a medium level of vertical relations and high transport costs, downstream production can take place partially in the small region, provided that the input supplier is also located there. But, as this equilibrium is nonstrict, it is likely that firms will switch to agglomeration in the large region. On the contrary, if vertical linkages are strong and transport costs are low, there exists a strict equilibrium with full agglomeration in the small region.

5 Conclusions

If interindustry complementarities are high and transport costs are low, a stable industrial cluster can arise in the peripheral region. ‘Globalization’ does not appear to threaten this possibility. However, there is a precondition for this desirable evolution to become real. Because the agglomeration in the core region is always an open possibility, the policymaker must somehow ‘select’ the equilibrium where firms cluster in the peripheral region. The role of regional policy appears to be irreplaceable in achieving this outcome.

In addition to what has already been said, the agglomeration in the core region Pareto dominates in terms of the firms’ payoffs the clustering of firms in the peripheral region. This fact strengthens the need for an active role of regional policy in order to benefit the consumers of the peripheral region and achieve interregional equity. It should be remarked, however, that, although payoff dominance appears as the most important feature of equilibrium selection in some deductive approaches (as in Harsanyi and Selten, 1988), it is not decisive in experimental games where other considerations such as avoiding strategic risk or the existence of an historical precedent play an equally important role (see, among others, van Huyck et al, 1991).

This paper contains several directions for further research. The most obvious one is to model the form that regional policy takes as a device for selecting an equilibrium of location. Two different possibilities arise: either the firms are induced to locate in the peripheral region by means of subsidies or other fiscal instruments, or through some kind of administrative command. Although the second instrument is seldom feasible in market economies, the first is a very common instrument of regional policy. Therefore, a possible extension would be to show how regionally based subsidies can shift the productive activity to locate in peripheral areas as a stable equilibrium.

Acknowledgements. The author wishes to thank Armando Pires, the editor of the journal, and three anonymous referees for helpful comments. The usual disclaimer applies. This paper had the support of the Research Unit on Complexity and Economics (UECE).

References

- Anderson S, Neven D, 1991, “Cournot competition yields spatial agglomeration” *International Economic Review* **32** 793–808
- Baldwin R, Robert-Nicoud F, 2000, “Free trade agreements without delocation” *Canadian Journal of Economics/Revue Canadienne d’Economie* **33** 766–786
- Combes P, 1997, “Industrial agglomeration under Cournot competition” *Annales d’Économie et de Statistique* **45** 161–182
- D’Aspremont C, Gabszewicz J, Thisse J, 1979, “On Hotelling ‘stability in competition’” *Econometrica* **47** 1145–1150

- Fujita M, 1981, "Location of firms with input transactions" *Environment and Planning A* **13** 1401–1414
- Fujita M, Thisse J, 1993, "Technological linkages and efficient location of indivisible activities: Koopmans–Beckmann and Von Thunen unified" *Journal of Urban Economics* **34** 118–141
- Gersbach H, Schmutzler A, 1999, "External spillovers, internal spillovers and the geography of production and innovation" *Regional Science and Urban Economics* **29** 679–696
- Gupta B, Pal D, Sarkar J, 1997, "Spatial Cournot competition and agglomeration in a model of location choice" *Regional Science and Urban Economics* **27** 261–282
- Harsanyi J, Selten R, 1988 *A General Theory of Equilibrium Selection in Games* (MIT Press, Cambridge, MA)
- Hwang H, Mai C, 1989, "On the optimum location of vertically related firms with simultaneous entry" *Journal of Regional Science* **29** 47–61
- Krugman P, 1991, "Increasing returns and economic geography" *Journal of Political Economy* **99** 483–499
- Krugman P, Venables A, 1990, "Integration and the competitiveness of the peripheral industry", in *Unity with Diversity in the European Economy: The Community's Southern Frontier* Eds C Bliss, J B Macedo (Cambridge University Press, Cambridge) pp 56–77
- Mai C, Peng S, 1999, "Cooperation vs competition in a spatial model" *Regional Science and Urban Economics* **29** 463–472
- Marshall A, 1920 *Principles of Economics* (Macmillan, London)
- Mayer T, 2000, "Spatial Cournot competition and heterogeneous production costs across locations" *Regional Science and Urban Economics* **30** 325–352
- The Economist* 1995, "A survey of cities", 29 July
- van Huyck J, Battalio R, Beil R, 1991, "Strategic uncertainty, equilibrium selection and coordination failure in average opinion games" *Quarterly Journal of Economics* **106** 885–910
- Venables A, 1996, "Equilibrium locations of vertically linked industries" *International Economic Review* **37** 341–359
- Weibull J, 1997 *Evolutionary Game Theory* (MIT Press, Cambridge, MA)

Appendix A

Detailed expressions of quantities in the third stage of the game [expression (4)]

$$q_{1a} = \frac{1}{3}n_a \frac{g - c + td(x_2, A) - \alpha k + \alpha t_k d(x_3, x_2) - 2td(x_1, A) - 2\alpha t_k d(x_3, x_1)}{f},$$

$$q_{2a} = \frac{1}{3}n_a \frac{g - c - 2td(x_2, A) - \alpha k - 2\alpha t_k d(x_3, x_2) + td(x_1, A) + \alpha t_k d(x_3, x_1)}{f},$$

$$q_{1b} = \frac{1}{3}n_b \frac{g - c + td(x_2, A) - \alpha k + \alpha t_k d(x_3, x_2) - 2td(x_1, B) - 2\alpha t_k d(x_3, x_1)}{f},$$

$$q_{2b} = \frac{1}{3}n_b \frac{g - c - 2td(x_2, B) - \alpha k - 2\alpha t_k d(x_3, x_2) + td(x_1, B) + \alpha t_k d(x_3, x_1)}{f}.$$

Appendix B

Detailed solution of the subgames that come after the first stage game

(1) Subgame where $x_1 = x_2 = x_3 = A$

According to equation (2), the profit functions of the downstream firms in the third stage are,

$$\pi_1 = (p_a - \alpha k)q_{1a} + (p_b - t - \alpha k)q_{1b},$$

$$\pi_2 = (p_a - \alpha k)q_{2a} + (p_b - t - \alpha k)q_{2b},$$

where the prices, following equation (3), are

$$p_a = 1 - \frac{q_{1a} + q_{2a}}{2},$$

and

$$p_b = 1 - (q_{1b} + q_{2b}).$$

The Nash equilibrium in the third stage is

$$q_{1a}^* = q_{2a}^* = \frac{2}{3}(1 - k\alpha),$$

$$q_{1b}^* = q_{2b}^* = \frac{1}{3}(1 - k\alpha - t).$$

The profit function of firm 3, as given by equation (5), is

$$\pi_3 = \alpha k(q_{1a}^* + q_{1b}^* + q_{2a}^* + q_{2b}^*).$$

The Nash equilibrium of the second stage is the profit-maximizing input price:

$$k^* = \frac{3 - t}{6\alpha}.$$

Substituting q_{1a}^* , q_{1b}^* , q_{2a}^* , q_{2b}^* , and k^* in the profit functions, we obtain the payoffs in the first stage in terms of the parameter t :

$$\pi_1(A, A, A) = \pi_2(A, A, A) = \frac{1}{12} - \frac{1}{18}t + \frac{1}{12}t^2,$$

$$\pi_3(A, A, A) = \frac{1}{2} - \frac{1}{3}t + \frac{1}{18}t^2.$$

(2) Subgame with $x_1 = B$, $x_2 = x_3 = A$

According to equation (2), third-stage profit functions are

$$\pi_1 = [p_a - t - \alpha(k + t)]q_{1a} + [p_a - \alpha(k + t)]q_{1b},$$

$$\pi_2 = (p_a - \alpha k)q_{2a} + (p_b - t - \alpha k)q_{2b}.$$

The Nash equilibrium quantities in this stage are

$$q_{1a}^* = \frac{2}{3} - \frac{2}{3}\alpha k - \frac{4}{3}t - \frac{4}{3}\alpha t,$$

$$q_{2a}^* = \frac{2}{3} - \frac{2}{3}\alpha k + \frac{2}{3}t + \frac{2}{3}\alpha t,$$

$$q_{1b}^* = \frac{1}{3} + \frac{1}{3}t - \frac{1}{3}\alpha k - \frac{2}{3}\alpha t,$$

$$q_{2b}^* = \frac{1}{3} - \frac{2}{3}t - \frac{1}{3}\alpha k + \frac{1}{3}\alpha t.$$

Substituting the equilibrium quantities in the profit function of firm 3,

$$\pi_3 = \alpha k(q_{1a}^* + q_{1b}^* + q_{2a}^* + q_{2b}^*),$$

and maximizing the profit function in relation to k , we obtain the equilibrium price of the second stage of the game:

$$k^* = \frac{1}{4\alpha}(2 - t - \alpha t).$$

Substituting this value of k^* in q_{1a}^* , we obtain the quantity supplied in market A by downstream firm 1 in terms of the parameters α, t :

$$q_{1a}^* = \frac{1}{3} - \frac{7}{6}t - \frac{7}{6}\alpha t. \tag{B1}$$

Nonnegativity of q_{1a}^* is equivalent to

$$t \leq \frac{2}{7(1 + \alpha)}. \tag{B2}$$

This condition ensures that each downstream firm is active in each market for any possible location of firms. The maximum degree of cost asymmetry between two downstream firms occurs in this subgame in the market of region A. Although firm I bears the unit transport cost of the consumer good, t , and the unit transport cost of the intermediate good, αt , firm 2 bears neither of these. If the Cournot–Nash equilibrium quantity of firm 1 in market A is nonnegative, the same property holds for each firm in each market for every pair of locations.

Substituting the equilibrium quantities of the third stage and the equilibrium price of the input in the second stage in the profit functions, we obtain payoffs in terms of parameters t and α :

$$\pi_1(\mathbf{B}, \mathbf{A}, \mathbf{A}) = \frac{1}{12} - \frac{1}{4}t - \frac{7}{12}\alpha t + \frac{41}{48}t^2 + \frac{7}{8}\alpha t^2 + \frac{49}{48}\alpha^2 t^2,$$

$$\pi_2(\mathbf{B}, \mathbf{A}, \mathbf{A}) = \frac{1}{12} + \frac{1}{12}t + \frac{5}{12}\alpha t + \frac{11}{16}t^2 + \frac{5}{24}\alpha t^2 + \frac{25}{48}\alpha^2 t^2,$$

$$\pi_3(\mathbf{B}, \mathbf{A}, \mathbf{A}) = \frac{1}{2} - \frac{1}{2}t - \frac{1}{2}\alpha t + \frac{1}{8}t^2 + \frac{1}{4}\alpha t^2 + \frac{1}{8}\alpha^2 t^2.$$

(3) Subgame with $x_1 = x_3 = \mathbf{A}, x_2 = \mathbf{B}$

This case is symmetric to the previous one. Therefore, we have

$$\pi_1(\mathbf{A}, \mathbf{B}, \mathbf{A}) = \pi_2(\mathbf{B}, \mathbf{A}, \mathbf{A}),$$

$$\pi_2(\mathbf{A}, \mathbf{B}, \mathbf{A}) = \pi_1(\mathbf{B}, \mathbf{A}, \mathbf{A}),$$

$$\pi_3(\mathbf{A}, \mathbf{B}, \mathbf{A}) = \pi_3(\mathbf{B}, \mathbf{A}, \mathbf{A}).$$

(4) Subgame where $x_1 = x_2 = \mathbf{B}, x_3 = \mathbf{A}$

The profit functions of downstream firms in the third stage are

$$\pi_1 = [p_a - t - \alpha(k + t)]q_{1a} + [p_b - \alpha(k + t)]q_{1b},$$

$$\pi_2 = [p_a - t - \alpha(k + t)]q_{2a} + [p_b - \alpha(k + t)]q_{2b}.$$

The Nash equilibrium quantities in this stage are

$$q_{1a}^* = q_{2a}^* = \frac{2}{3} - \frac{2}{3}t - \frac{2}{3}\alpha k - \frac{2}{3}\alpha t,$$

$$q_{1b}^* = q_{2b}^* = \frac{1}{3} - \frac{1}{3}\alpha k - \frac{1}{3}\alpha t.$$

The profit function of the upstream firm is

$$\pi_3 = \alpha k(q_{1a}^* + q_{1b}^* + q_{2a}^* + q_{2b}^*).$$

Substituting the equilibrium quantities and maximizing the profit function in relation to k , we obtain the equilibrium price of the input in the second stage.

$$k^* = \frac{1}{6\alpha}(3 - 2t - 3\alpha t).$$

Substituting the equilibrium quantities q_{1a}^* , q_{1b}^* , q_{2a}^* , q_{2b}^* , and the input price k^* in the profit functions, we obtain payoffs in terms of α and t :

$$\pi_1(\mathbf{B}, \mathbf{B}, \mathbf{A}) = \pi_2(\mathbf{B}, \mathbf{B}, \mathbf{A}) = \frac{1}{12} - \frac{1}{9}t - \frac{1}{6}\alpha t + \frac{1}{9}t^2 + \frac{1}{9}\alpha t^2 + \frac{1}{12}\alpha^2 t^2,$$

$$\pi_3(\mathbf{B}, \mathbf{B}, \mathbf{A}) = \frac{1}{2} - \frac{2}{3}t - \alpha t + \frac{2}{9}t^2 + \frac{2}{3}\alpha t^2 + \frac{1}{2}\alpha^2 t^2.$$

(5) Subgame where $x_1 = x_2 = \mathbf{A}$, $x_3 = \mathbf{B}$

The third-stage profit functions of the downstream functions are

$$\pi_1 = [p_a - \alpha(k + t)]q_{1a} + [p_b - t - \alpha(k + t)]q_{1b},$$

$$\pi_2 = [p_a - \alpha(k + t)]q_{2a} + [p_b - t - \alpha(k + t)]q_{2b}.$$

The equilibrium quantities of the third stage are

$$q_{1a}^* = q_{2a}^* = \frac{2}{3} - \frac{2}{3}\alpha k - \frac{2}{3}\alpha t,$$

$$q_{1b}^* = q_{2b}^* = \frac{1}{3} - \frac{1}{3}t - \frac{1}{3}\alpha k - \frac{1}{3}\alpha t.$$

Maximizing the profit function of the upstream firm,

$$\pi_3 = \alpha k(q_{1a}^* + q_{1b}^* + q_{2a}^* + q_{2b}^*),$$

yields the equilibrium price of the input in the second stage:

$$k^* = \frac{1}{6\alpha}(3 - 3\alpha t - t).$$

Substituting the equilibrium quantities and input price in the profit functions, we obtain payoffs defined in terms of the parameters t and α :

$$\pi_1(\mathbf{A}, \mathbf{A}, \mathbf{B}) = \pi_2(\mathbf{A}, \mathbf{A}, \mathbf{B}) = \frac{1}{12} - \frac{1}{6}\alpha t - \frac{1}{18}t + \frac{1}{12}\alpha^2 t^2 + \frac{1}{18}\alpha t^2 + \frac{1}{12}t^2,$$

$$\pi_3(\mathbf{A}, \mathbf{A}, \mathbf{B}) = \frac{1}{2} - \alpha t - \frac{1}{3}t + \frac{1}{2}\alpha^2 t^2 + \frac{1}{3}\alpha t^2 + \frac{1}{18}t^2.$$

(6) Subgame where $x_1 = x_3 = \mathbf{B}$, $x_2 = \mathbf{A}$

The third-stage profit functions of the downstream firms are

$$\pi_1 = (p_a - t - \alpha k)q_{1a} + (p_b - \alpha k)q_{1b},$$

$$\pi_2 = [p_a - \alpha(k + t)]q_{2a} + [p_b - t - \alpha(k + t)]q_{2b}.$$

The Nash equilibrium quantities are

$$q_{1a}^* = \frac{2}{3} - \frac{4}{3}t - \frac{2}{3}\alpha k + \frac{2}{3}\alpha t,$$

$$q_{2a}^* = \frac{2}{3} + \frac{2}{3}t - \frac{2}{3}\alpha k - \frac{4}{3}\alpha t,$$

and

$$q_{1b}^* = \frac{1}{3} - \frac{1}{3}\alpha k + \frac{1}{3}t + \frac{1}{3}\alpha t,$$

$$q_{2b}^* = \frac{1}{3} - \frac{1}{3}\alpha k - \frac{2}{3}t - \frac{2}{3}\alpha t.$$

The equilibrium price of the input in the second stage follows from the maximization of the profit function of the upstream firm, where the quantities assume their equilibrium values in the third stage of the game:

$$\pi_3 = \alpha k(q_{1a}^* + q_{1b}^* + q_{2a}^* + q_{2b}^*).$$

Therefore, the equilibrium price of the intermediate good is

$$k^* = \frac{1}{4\alpha}(2 - t - \alpha t).$$

Substituting the equilibrium quantities and input price in the profit functions, we obtain payoffs in terms of the parameters α and t :

$$\pi_1(\text{B}, \text{A}, \text{B}) = \frac{1}{12} - \frac{1}{4}t + \frac{5}{12}\alpha t + \frac{41}{48}t^2 - \frac{5}{8}\alpha t^2 + \frac{25}{48}\alpha^2 t^2,$$

$$\pi_2(\text{B}, \text{A}, \text{B}) = \frac{1}{12} + \frac{1}{12}t - \frac{7}{12}\alpha t + \frac{11}{16}t^2 - \frac{7}{24}\alpha t^2 + \frac{49}{48}\alpha^2 t^2,$$

$$\pi_3(\text{B}, \text{A}, \text{B}) = \frac{1}{2} - \frac{1}{2}t - \frac{1}{2}\alpha t + \frac{1}{8}t^2 + \frac{1}{4}\alpha t^2 + \frac{1}{8}\alpha^2 t^2.$$

(7) Subgame where $x_1 = \text{A}$, $x_2 = x_3 = \text{B}$

This case is symmetric to the previous one. Hence

$$\pi_1(\text{A}, \text{B}, \text{B}) = \pi_2(\text{B}, \text{A}, \text{B}),$$

$$\pi_2(\text{A}, \text{B}, \text{B}) = \pi_1(\text{B}, \text{A}, \text{B}),$$

$$\pi_3(\text{A}, \text{B}, \text{B}) = \pi_3(\text{B}, \text{A}, \text{B}).$$

(8) Subgame where $x_1 = x_2 = x_3 = \text{B}$

The third-stage profit functions of the downstream firms are

$$\pi_1 = (p_a - t - \alpha k)q_{1a} + (p_b - \alpha k)q_{1b},$$

$$\pi_2 = (p_a - t - \alpha k)q_{2a} + (p_b - \alpha k)q_{2b}.$$

The Nash equilibrium quantities of this stage are

$$q_{1a}^* = q_{2a}^* = \frac{2}{3} - \frac{2}{3}t - \frac{2}{3}\alpha k,$$

$$q_{1b}^* = q_{2b}^* = \frac{1}{3} - \frac{1}{3}\alpha k.$$

The equilibrium price of the intermediate good can be obtained by maximizing the profit function of the input supplier, where quantities assume their third-stage equilibrium values:

$$\pi_3 = \alpha k(q_{1a}^* + q_{1b}^* + q_{2a}^* + q_{2b}^*).$$

The equilibrium monopoly price is

$$k^* = \frac{1}{6\alpha}(3 - 2t).$$

Substituting the equilibrium quantities and input price in the profit functions, we obtain payoffs in terms of the parameter t :

$$\pi_1(\mathbf{B}, \mathbf{B}, \mathbf{B}) = \pi_2(\mathbf{B}, \mathbf{B}, \mathbf{B}) = \frac{1}{12} - \frac{1}{9}t + \frac{1}{9}t^2,$$

$$\pi_3(\mathbf{B}, \mathbf{B}, \mathbf{B}) = \frac{1}{2} - \frac{2}{3}t + \frac{2}{9}t^2.$$