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REGIONAL POLICY AND INDUSTRIAL LOCATION DECISIONS

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In this paper we analyse whether different infrastructures affect the location decisions of economic agents. Taking the model in Martin and Rogers (1995), a complete range of infrastructure classes that a region can have is considered. We consider domestic, international transport, international export and international import infrastructures. The principal conclusion is that the optimal regional policy that attracts industrial location is the one that improves domestic and international export infrastructures. Superior domestic and export infrastructures also increase welfare.

Keywords: Public infrastructure, industrial location.

(*JEL* H54, R12)

1. Introduction

Traditionally, the incorporation of state infrastructures in economic models has been made in the belief that they are one more input in the aggregate production function (Arrow and Kurz, 1970, Barro, 1990). The empirical literature[1] also treats public capital as a factor coexisting with private factors within the production function. This literature analyses the productivity of public capital, the possible existence of a expulsion effect on private capital and the power of different regional infrastructure endowments in explaining inter-regional differences in per capita income.

In this paper we are interested in theoretically exploring the effects exercised by state infrastructure on economic agents' location decisions. Following Martin and Rogers (1995), we interpret public infrastructure in its widest sense, so that it includes any goods or services

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[1] See, for example, Aschauer (1989), García-Milá and McGuire (1992), García-Milá *et al.* (1996) and Boarnet (1998).

provided by the state which are capable of facilitating the connection between production and consumption. Considered in this way, infrastructures are means of transport and communication, but also elements that are not usually included in the concept such as legal ordinances or the level of public security.

This reinterpretation of infrastructure provides us the additional advantage of being able to introduce infrastructures in the model in a simple manner. Good infrastructures result in low transaction costs; poor infrastructures represent a situation where trade is difficult and gives rise to high entry or transportation costs. We can, hence, take it that these costs associated with transactions have the iceberg form proposed by Samuelson (1954), in such a way that a portion of each transported good is lost and not eventually consumed, and this portion is bigger the worse the infrastructure.

Together with the product differentiation model of Dixit and Stiglitz (1977), one of the instruments most closely associated with the theoretical literature on Economic Geography is the use of iceberg type costs (Krugman, 1991). While Krugman (1991), Krugman and Venables (1995) and Puga (1999) only consider transport costs, Krugman and Livas (1996) and Puga and Venables (1999) interpret such costs as tariffs. Martin and Rogers (1995) is the first paper to argue that iceberg costs can be used to represent the quality of public infrastructures. In this paper we adopt the latter approach.

Martin and Rogers (1995) distinguish between two classes of infrastructure: those enabling domestic exchanges (domestic infrastructure) and those expediting international transactions (international infrastructure) in a two-country model. Their main results are the following: i) if the infrastructure facilitates transactions within the region (domestic infrastructure), then firms are attracted to the region, ii) if the infrastructure facilitates interchange between the two regions or countries (international infrastructure), only the country that also possesses better domestic infrastructure captures firms and iii) any improvement in infrastructures, of whatever type, increases welfare. Martin and Rogers do not differentiate between export and import infrastructure "because it is hard to imagine many types of infrastructure which facilitate exports but not imports, or vice versa" (page 339). We, however, argue that such a distinction is important and that in real world situations such infrastructures do exist. We further distinguish between the different forms of infrastructure that can exist in a country. We distinguish between the infrastructures based on the transactions they facilitate, i. e., domestic, international transport (identical in both directions), international export and international import infrastructure.

The introduction of the novel distinction between transport, import, and export infrastructures emerges as relevant and its effects on industrial location are perfectly defined. Our distinction is supported by the empirical evidence.

In the case of Spain, domestic infrastructures are defined in the "Plan for Modernisation of Domestic Trade" (1995) on which all domestic trade policy is based. The Plan has two objectives: to guarantee supply of consumption needs and reduce commercialisation costs. Multiple measures have been proposed to fulfil these objectives: research into specific markets, professional training of sector employees (who represent 14 % of Spain's employment), financial funding to modernise the commercial sector (a task undertaken by the "Institute for Reform of Commercial Structures", IRESCO), information to consumers, measures to defend competition, actions in seasonal commerce and areas without supply, regulation of opening hours and discount sales periods, commercial town planning measures and financial aid for new technology development. In these examples we have tried to classify some domestic infrastructure items. Of course, highways, airports and domestic communication networks are also domestic infrastructures.

It is easy to imagine the international transport and communication infrastructure: highways, airports, communication networks. These by definition are the same for both countries.

The difficulty is distinguishing between export and import infrastructure. However, in our new extended concept of infrastructure, it is possible to classify exclusively import and exclusively export infrastructure. Included in the former are trade policy measures such as duties, quotas and a wide range of the non-duty category of trade barriers. All these, evidently, are taken as negative import infrastructures.

State activities dedicated exclusively to facilitate and foster exports (export infrastructure) are less well-known[2]. In the case of Spain, state regulation is articulated through the "Plan for Export Promotion". Among the instruments of financial character we find export credit

[2]Seringhaus and Rosson (1990) provide an exposition of these types of measures for developed countries.

(together with its complementary instrument the "Agreement for Reciprocal Adjustment of Interests"), export credit insurance and the "Development Aid Fund". Among the measures aimed at promoting exports are state subsidies for firm attendance at international trade fairs, sector programmes and training programmes. Coexisting with all these actions, is the "Institute for Foreign Trade" (ICEX), founded in 1987 to replace the "National Institute for Export Promotion" (INFE). ICEX activities in support of exports have been implemented through three actions: promotion and control of export consortia and exporter associations, creation of a data base including everything related to the Spanish export sector, and transmission and publication of the information of interest for companies who sell outside the national territory.

Based on this, we think that there does exist a real life counterpart for our differentiation between international transport, import and export infrastructure. In other words, we are incorporating asymmetries into the Martin and Rogers (1995) model, enabling countries to show different biases, or tendencies, with respect to transactions (according to whether these are sales or purchases).

Furthermore, and as can be observed in the real world, the foreign policies of different countries are interrelated in such a way that a change in the trade policy of one country frequently provokes a reaction or reply in the trade policy of the country with which it interchanges. This is even more relevant in our model of only two countries. This fact induces us to consider the convenience of introducing a relationship between both policies into our model so that, for example, if one country establishes an import tariff (worsening its international import infrastructure in our terminology), the other responds with an export subsidy (thus improving its international export infrastructure). For this reason, we establish a functional dependence between the export infrastructures of one country and the import infrastructures of the other that shows the strategic interdependence between them.

We conclude that if a region wants to attract firms it must improve its domestic and international export infrastructure. Better transport, or import, infrastructure in principle produce an indeterminate effect. The effects on welfare replicate the results regarding the location of firms. Thus, more developed domestic and export infrastructure increases welfare, while transport and import infrastructure do not give a clear result.

The paper is organised as follows. In Section 2 we show the basic model. In Section 3 we analyse the equilibrium location of the firms between the two countries. Section 4 explores how sensitive firm location is to different types of infrastructure improvement policies. Section 5 concludes.

2. The model

There are two countries or regions, Home (H) and Foreign (F). In each country the representative consumer maximises the following Cobb-Douglas utility function:

$$U = \frac{D^{\alpha} Y^{1-\alpha}}{\alpha^{\alpha} (1-\alpha)^{1-\alpha}} \qquad [1]$$

where Y is the numeraire and D a composite of differentiated goods:

$$D = \left[\sum_{i=1}^{N} D_i^{1-\frac{1}{\sigma}} \right]^{\frac{1}{1-\frac{1}{\sigma}}} \qquad \sigma > 1 \qquad [2]$$

where N is the total number of varieties in H and F together: $N = n + n^*$. As is standard, the asterisk represents the foreign country. Expression [2] has Constant Elasticity of Substitution and is used because it allows an endogenous analysis of firm entry and exit from each of the regions. Note how this influences the geographic location of the industrial sector. Further, the CES function assumes that no pair of differentiated goods is perfectly substitutable, and hence the output of any firm will be consumed by every consumer in the economy.

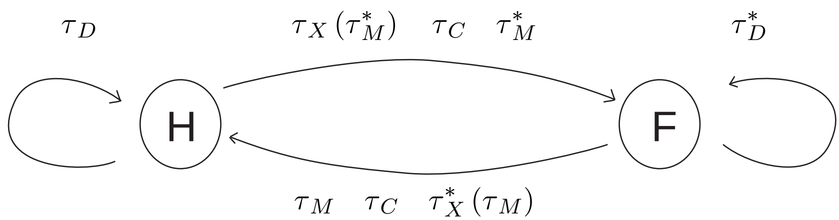
The budgetary restriction of a consumer in H is:

$$I = \sum_{i=1}^{n} \tau_D p_i D_i + \sum_{j=n+1}^{N} \tau_{\times}^{*} (\tau_M) \tau_M \tau_C p_j^* D_j + Y \qquad [3]$$

while that of F is given by:

$$I^* = \sum_{j=1}^{n^*} \tau_D^* p_j^* D_j^* + \sum_{i=n^*+1}^{N} \tau_{\times} (\tau_M^*) \tau_M^* \tau_C p_i D_i^* + Y^* \qquad [4]$$

where I is individual income, p_i and p_j^* are home and foreign prices and τ represents iceberg type costs, which work for differentiated goods in accordance with the following scheme:



τ_j reflects the proportion of the good lost in transit. Hence for H, only $\tau_D^{-1} < 1$ of each unit of the goods produced is available for the domestic consumer, while for each unit sent from F to H only $(\tau_M \tau_C \tau_X^*(\tau_M))^{-1} < 1$ actually reaches the consumer. Throughout the article we assume that $\tau_D < \tau_M \tau_C \tau_X^*(\tau_M)$ and $\tau_D^* < \tau_X(\tau_M^*)\tau_C \tau_M^*$; i. e., costs are lower when the goods are produced domestically than when manufactured abroad.

These τ_j costs are the ones that Martin and Rogers identify with the quality of a countries' public infrastructure. Thus τ_D relates to the domestic infrastructure level of H in such a way that a decline in τ_D denote improvements in this type of infrastructure. Parameters τ_X and τ_X^* (τ_M and τ_M^*) deal with the quality of international export (import) infrastructure, while τ_C represents the quality of international transport infrastructure (identical in both directions). With this approach we complete the whole possible range of arguments regarding the different types of transport costs–infrastructure. As a result, Martin and Rogers (1995) appear as a special case in our model (i. e., $\tau_M \tau_C \tau_X^*(\tau_M) = \tau_X(\tau_M^*)\tau_C \tau_M^* = \tau_I \tau_I^*$, with $\tau_I \tau_I^*$ being the level of international infrastructure).

We assume that each country reacts immediately to changes occurring in the import infrastructure of the other country. That is, Home will sell its products in Foreign at a lower price, the better Foreign's import infrastructure is. However, if Foreign's import infrastructure is low quality, then Home will try to improve its export infrastructure to enable it to sell its products in Foreign at a lower price. Hence the export infrastructure of a country depends on the import infrastructure of another country in the following way:

$$\begin{aligned} \tau_X &= \tau_X(\tau_M^*) \\ \frac{\partial \tau_X}{\partial \tau_M^*} &\prec 0 \end{aligned} \qquad \begin{aligned} \tau_X^* &= \tau_X^*(\tau_M) \\ \frac{\partial \tau_X^*}{\partial \tau_M} &\prec 0 \end{aligned}$$

Defining $\rho_X = \tau_X^{1-\sigma}$ and similarly for ρ_X^*, ρ_D, ρ_D^*, ρ_M, ρ_M^* and ρ_C we can write:

$$\begin{aligned} \rho_X &= \rho_X(\rho_M^*) \\ \frac{\partial \rho_X}{\partial \rho_M^*} &\prec 0 \end{aligned} \qquad \begin{aligned} \rho_X^* &= \rho_X^*(\rho_M) \\ \frac{\partial \rho_X^*}{\partial \rho_M} &\prec 0 \end{aligned}$$

As τ_j and σ are larger than unity, ρ_j is an indicator between 0 and 1 of the corresponding infrastructure[3] level (the greater ρ_j, the greater infrastructure quality).

We can interpret the derivatives in the following manner. If a country decides to raise its import tariffs (worse import infrastructure) to hamper entry of foreign products to its market, the other country reacts by raising, for example (various instruments are available) its export subsidies (better exports infrastructure).

Labour is internationally immobile and intersectorially mobile. Differentiated products consume capital and labour in manufacture use; a unit of capital is necessary to produce a product variety, so that the total number of varieties is limited by the world wide amount of capital endowment. Each different variety has the same unit labour cost, equal to β. Hence maximising profits requires that marginal revenue, $p_i(1-1/\sigma)$, should equal marginal cost, $\omega\beta$, so that $p_i = \omega\beta\sigma/(\sigma-1)$, where ω is the wage.

Returns on capital are equal to the difference between revenues and labour costs:

$$r = p_i x_i\left(p_i\right) - \omega\beta x_i\left(p_i\right) = \frac{\omega\beta x}{\sigma - 1} \qquad [5]$$

where x is the scale of a domestic producer firm for a particular product.

[3] As by hypothesis $\tau_D < \tau_M \tau_C \tau_X^*(\tau_M)$ and $\tau_D^* < \tau_X(\tau_M^*)\tau_C\tau_M^*$, its equivalents in terms of $\rho_j : \rho_D > \rho_M \rho_C \rho_X^*(\rho_M)$ and $\rho_D^* > \rho_X(\rho_M^*)\rho_C\rho_M^*$ are also fulfilled.

Good Y is produced with constant returns and only uses labour and has a technical coefficient of one. As it is the numeraire good, maximisation of benefits results in $\omega = 1$. Each domestic consumer offers inelastically one unit of labour and possesses K/L units of capital, hence their individual income is $I = 1 + rK/L$.

Resolving the problems of the consumers in H, the first order equations are given by:

$$D_i = \frac{\sigma-1}{\sigma\beta}\frac{\rho_D \alpha I}{\tau_D\left(n\rho_D + n^*\rho_X^*\left(\rho_M\right)\rho_M\rho_C\right)} \qquad [6]$$

$$D_j = \frac{\sigma-1}{\sigma\beta}\frac{\rho_X^*\left(\rho_M\right)\rho_M\rho_C\alpha I}{\tau_X^*\left(\tau_M\right)\tau_M\tau_C\left(n\rho_D + n^*\rho_X^*\left(\rho_M\right)\rho_M\rho_C\right)} \qquad [7]$$

$$\mathrm{Y} = (1-\alpha) I \qquad [8]$$

with $0 < \rho_j^h < 1, h =$ home or foreign (*), $j = D, X, M, C$, being the indicator of the quality of the corresponding infrastructure.

3. Location equilibrium of firms

In an autarky, industrial location is completely determined by the respective capital endowments: there are K firms in H and K^* firms in F. When goods and capital flows are not restricted, the ownership of capital does not vary, but its physical location (and with it, that of the firms) does change. In this case, four equilibrium equations define the location of firms. The first two show the scale of the firms of the differentiated good in each country:

$$x = \frac{\sigma-1}{\sigma\beta}$$
$$\left[\frac{\rho_D\alpha LI}{n\rho_D + n^*\rho_X^*\left(\rho_M\right)\rho_M\rho_C} + \frac{\rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\alpha L^* I^*}{n^*\rho_D^* + n\rho_X\left(\rho_M^*\right)\rho_M^*\rho_C}\right] \qquad [9]$$

$$x^* = \frac{\sigma-1}{\sigma\beta}$$
$$\left[\frac{\rho_D^*\alpha L^* I^*}{n^*\rho_D^* + n\rho_X\left(\rho_M^*\right)\rho_M^*\rho_C} + \frac{\rho_X^*\left(\rho_M\right)\rho_M\rho_C\alpha LI}{n\rho_D + n^*\rho_X^*\left(\rho_M\right)\rho_M\rho_C}\right] \qquad [10]$$

The third one arises from the free movement of capital between countries, in such a way that $r = r^*$, implying (from [5]) that $x = x^*$. Finally, the total number of firms, or varieties, is given by the world wide capital endowment, $n + n^* = K + K^*$. The previous expressions, after certain algebra, lead to:

$$x = x^* = \frac{\alpha(\sigma - 1)}{\beta(\sigma - \alpha)} \frac{L + L^*}{K + K^*} \quad [11]$$

$$n = \frac{\sigma - \alpha}{\sigma} \frac{K + K^*}{L + L^*}$$

$$\left[\frac{\rho_D^* L I}{\rho_D^* - \rho_X(\rho_M^*)\rho_M^* \rho_C} - \frac{\rho_X^*(\rho_M)\rho_M \rho_C L^* I^*}{\rho_D - \rho_X^*(\rho_M)\rho_M \rho_C} \right] \quad [12]$$

$$n^* = \frac{\sigma - \alpha}{\sigma} \frac{K + K^*}{L + L^*}$$

$$\left[\frac{\rho_D L^* I^*}{\rho_D - \rho_X^*(\rho_M)\rho_M \rho_C} - \frac{\rho_X(\rho_M^*)\rho_M^* \rho_C L I}{\rho_D^* - \rho_X(\rho_M^*)\rho_M^* \rho_C} \right] \quad [13]$$

Replacing I and I^* in [12] and [13] with their expressions and calculating, we arrive at:

$$n^* - n =$$

$$\frac{\dfrac{(\rho_D^* \rho_D - \rho_X(\rho_M^*)\rho_M^* \rho_C \rho_X^*(\rho_M)\rho_M \rho_C)}{\sigma(L + L^*)(\rho_D - \rho_X^*(\rho_M)\rho_M \rho_C)(\rho_D^* - \rho_X(\rho_M^*)\rho_M^* \rho_C)} \underline{[(L^* - L)(\sigma - \alpha)(K + K^*) + (K^* - K)\alpha(L + L^*)]}}{1}$$

$$+ \frac{(\rho_D^* \rho_X^*(\rho_M)\rho_M \rho_C - \rho_D \rho_X(\rho_M^*)\rho_M^* \rho_C)(K + K^*)(L + L^*)\sigma}{\sigma(L + L^*)(\rho_D - \rho_X^*(\rho_M)\rho_M \rho_C)(\rho_D^* - \rho_X(\rho_M^*)\rho_M^* \rho_C)} \quad [14]$$

PROPOSITION 1. *Given that, by hypothesis* $\rho_D > \rho_X^*(\rho_M)\rho_M \rho_C$ *and* $\rho_D^* > \rho_X(\rho_M^*)\rho_M^* \rho_C$, *a group of sufficient conditions that guarantees that [14] is negative is given by* $K > K^*, L > L^*$ *and* $\rho_D \rho_X(\rho_M^*)\rho_M^* \geq \rho_D^* \rho_X^*(\rho_M)\rho_M$.

These last expressions tell us that countries with greater income (more capital and more labour) tend to have a greater number of firms. This result can be related to what the literature of the New Economic Geography denominates 'forward linkages', according to which firms want to be near other firms because they then enjoy better access to factor markets. As for the infrastructures, some conclusions are already implied with this simple analysis, i. e. domestic and export infrastructures play in favour of attracting firms; transport and import infrastructures do not have a clear effect[4].

Why do export and domestic infrastructures favour industrial location in H? Because both, in contrast to import and transport infrastructures, unequivocally increase the demand the firms located in H have to satisfy. This better access to the markets for products and to consumers constitutes, in the presence of transport costs, a 'backward linkage'; this also represents a result which has to do with the so-called 'home market effect', according to which the region with greater demand for its products possesses a proportionally larger manufacturing sector than the other region.

3.1. Countries of identical size $(L = L^*)$

If $K = K^*$ then [14] is:

$$n^* - n = 2(K - n) = 2K \frac{\left(\rho_D^* \rho_X^* (\rho_M) \rho_M \rho_C - \rho_D \rho_X (\rho_M^*) \rho_M^* \rho_C\right)}{\left(\rho_D - \rho_X^* (\rho_M) \rho_M \rho_C\right)\left(\rho_D^* - \rho_X (\rho_M^*) \rho_M^* \rho_C\right)} \qquad [15]$$

Let $\rho_D = \rho_D^*$, so that the only differences in infrastructure affect import and export infrastructures.

Proposition 2. *Let us suppose that* $K = K^*, L = L^*$ *and* $\rho_D = \rho_D^*$, *then* $n > n^*$ *if and only if* $\rho_X(\rho_M^*)\rho_M^* > \rho_X^*(\rho_M)\rho_M$.

That is, in order to attract firms, H is interested in an excellent export infrastructure. However, we cannot say anything about the import infrastructure. The export infrastructure of F plays, clearly, in the opposite direction.

Proposition 3. *Let us suppose now that* $K = K^*, L = L^*$ *and* $\rho_D = \rho_D^*$, *then a sufficient condition for* $n > n^*$ *is that* $\rho_X(\rho_M^*)\rho_M^* \geq \rho_X^*(\rho_M)\rho_M$.

[4]In Martin and Rogers, one deduces that countries with greater income and better domestic infrastructure attract a greater number of firms. Obviously, the conclusions we obtain in this paper regarding the other types of infrastructure are not comparable to any results of the original model.

Let's take the case in which the countries differ only in their capital endowment[5], imposing, without loss of generality, $K > K^*$. Equation [14] then becomes:

$$n^* - n = \frac{\sigma\left(K+K^*\right)\left(\rho_X^*\left(\rho_M\right)\rho_M\rho_C - \rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\right)\rho_D}{\sigma\left(\rho_D - \rho_X^*\left(\rho_M\right)\rho_M\rho_C\right)\left(\rho_D - \rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\right)} + \frac{\alpha\left(K^*-K\right)\left(\rho_D^2 - \rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\rho_X^*\left(\rho_M\right)\rho_M\rho_C\right)}{\sigma\left(\rho_D - \rho_X^*\left(\rho_M\right)\rho_M\rho_C\right)\left(\rho_D - \rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\right)} \quad [16]$$

PROPOSITION 4. *Let us suppose that* $K > K^*, L = L^*$ *and* $\rho_D = \rho_D^*$*, then, once again, a sufficient condition to ensure that the country with most income has a greater number of firms is* $\rho_X(\rho_M^*)\rho_M^* \geq \rho_X^*(\rho_M)\rho_M$.

That is, the export infrastructure favours attracting superior economic activity. Note that in the Martin and Rogers model, $K > K^*$ implies automatically that $n > n^*$; in our case, as we take different import and export infrastructures, we need to add to $K > K^*$ the above mentioned condition of $\rho_X(\rho_M^*)\rho_M^* \geq \rho_X^*(\rho_M)\rho_M$.

The physical transfer of capital from H to F is given by:

$$K - n = \frac{K+K^*}{2}\frac{\left[\rho_X^*(\rho_M)\rho_M\rho_C - \rho_X(\rho_M^*)\rho_M^*\rho_C\right]\rho_D}{\left(\rho_D - \rho_X^*\left(\rho_M\right)\rho_M\rho_C\right)\left(\rho_D - \rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\right)} + \frac{K^*-K}{2}\left[\frac{\alpha}{\sigma}\frac{\rho_D^2 - \rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\rho_X^*\left(\rho_M\right)\rho_M\rho_C}{\left(\rho_D - \rho_X^*\left(\rho_M\right)\rho_M\rho_C\right)\left(\rho_D - \rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\right)} - 1\right] \quad [17]$$

whose sign (positive or negative) is not determined, the same as in the Martin and Rogers model. On one hand, a country with less capital produces less differentiated goods, thus making it an attractive location for firms. On the other hand, this country has less income, so its demand for differentiated goods is smaller, making it less attractive. These are the two opposing forces which leave the sign of [17] undetermined. Precisely, it can be seen that the sign of the two square brackets in [17] is not determined, which goes to emphasize the indeterminacy to which we refer to in this paragraph.

[5] Of course, throughout this section the international import and export infrastructures of the countries are different.

3.2. Countries of different size ($L \neq L^*$)

We now analyse the case where $K = K^*$ and $\rho_D = \rho_D^*$. That is, expression [14] now gives us:

$$n^* - n = 2(K-n) =$$
$$\frac{2K}{L+L^*}\frac{\left(\rho_D^2 - \rho_X(\rho_M^*)\rho_M^*\rho_C\rho_X^*(\rho_M)\rho_M\rho_C\right)(L^*-L)(\sigma-\alpha)}{\sigma\left(\rho_D-\rho_X^*(\rho_M)\rho_M\rho_C\right)\left(\rho_D-\rho_X(\rho_M^*)\rho_M^*\rho_C\right)}$$
$$+\frac{\left(\rho_X^*(\rho_M)\rho_M\rho_C-\rho_X(\rho_M^*)\rho_M^*\rho_C\right)\rho_D(L+L^*)\sigma}{\sigma\left(\rho_D-\rho_X^*(\rho_M)\rho_M\rho_C\right)\left(\rho_D-\rho_X(\rho_M^*)\rho_M^*\rho_C\right)} \quad [18]$$

PROPOSITION 5. *Supposing that $K = K^*, L > L^*$ and $\rho_D = \rho_D^*$, then a sufficient condition for $n > n^*$ is $\rho_X(\rho_M^*)\rho_M^* \geq \rho_X^*(\rho_M)\rho_M$.*

This condition again implies that export infrastructures play in favour of attracting firms, while international import infrastructures do not have a clear effect.

Summarising, we can say that regarding the location equilibrium of firms good export infrastructure helps the country in question to attract firms, as they are able to sell cheaply to the other country and consequently face a greater demand; in contrast transport and import infrastructure do not exert a clear influence. This sufficient condition, valid under diverse suppositions, of $\rho_X(\rho_M^*)\rho_M^* \geq \rho_X^*(\rho_M)\rho_M$ (or with strict inequality in proposition 2 and being in this case a necessary and sufficient condition), can be re-written as: $\rho_X(\rho_M^*)\big/\rho_X^*(\rho_M) \geqslant \rho_M\big/\rho_M^*$.

This implies that if one country has a superior relative export infrastructure (compared to its import infrastructure, that is to say, it presents a favourable export bias), it will have a greater number of firms.

What is the principal mechanism explaining the behaviour of international export infrastructure, when it comes to justifying the spatial location of firms? When economies of scale are present, firms have incentives to locate wherever demand is stronger. A high ρ_X (a low τ_X) makes the sale price in F of differentiated goods produced in H low, and hence firms in H benefit from higher foreign demand for their products. Note that this result is valid whatever the relative size of the countries, so that an improvement in export infrastructures can offset initial disadvantages in terms of capital and labour endowments. The relevance of this result (that international export infrastructures attract industry) is remarkable in that it has no possible counterpart in the original Martin and Rogers model. In effect, because their model does not differentiate between international import and export infrastructures, the above result is impossible to obtain.

4. Improvement in infrastructures

Let us suppose that country H devises a policy to improve its infrastructures. We analyse the effects of this policy on industrial location and welfare. In the first place we look at a case in which either infrastructure is externally financed (supranational funds, for example) or is infrastructure not bearing cost (a change in legal ordinances on retail distribution, for example). In either of the two cases the income of H, I, does not suffer a loss as a result of achieving a better infrastructure provision.

To carry out the analysis we must analyse the sign of $\partial(n^* - n)/\partial\rho_j$ in [14] or that of $\partial n/\partial\rho_j$ in [12], $j = D$, X, M, C. $\partial(n^* - n)/\partial\rho_j$ gives us how the net resulting number of firms in F varies with respect to the level of type j infrastructure; $\partial n/\partial\rho_j$ shows how the number of firms in H responds when the quality of type j infrastructure varies. Given that these derivatives have different signs and the latter is much easier to obtain, we opt for this choice. At the same time, we see immediately that the signs of these derivatives with respect to the ρ_j parameters hold under the simplifying supposition $K = K^*, L = L^*$.

The sign of the relevant derivatives is as follows:

$$\frac{\partial n}{\partial\rho_D} \succ 0 \qquad \frac{\partial n}{\partial\rho_X} \succ 0 \qquad \frac{\partial n}{\partial\rho_M} ?0 \qquad \frac{\partial n}{\partial\rho_C} ?0 \qquad [19]$$

Investment in domestic infrastructure attracts firms (this result replicates Martin and Rogers), as does an improvement in export infrastructure. These conclusions corroborate others deduced earlier. That is, international regional policy designed to attract firms consists of improving exclusively all infrastructures which can bring greater efficiency in policies tending to encourage exports.

Investment in international import, or transport, infrastructure does not have clear effects on the number of firms. First we analyse what happens if import infrastructure is improved. In this case we conclude that:

PROPOSITION 6. *In the general case* ($K \neq K^*, L \neq L^*$ *and* $\rho_D \neq \rho_D^*$), $\frac{\partial n}{\partial \rho_M} \succ 0$ *if and only if* $E_{\rho_X^*} \succ 1$ *defining this elasticity as:*

$$E_{\rho_X^*} = -\frac{\rho_M}{\rho_X^*(\rho_M)} \frac{\partial \rho_X^*(\rho_M)}{\partial \rho_M}$$

That is, import infrastructure investment attracts firms when the percentage variation it causes in the import infrastructure is less than the change caused in the export infrastructure of the other country. Thus, this is a relative measure of infrastructure improvement. Hence we can imagine, for example, that H cuts import tariffs (ρ_M increases), and F reacts by cutting its export subsidies (ρ_X^* decreases); if the fall in export subsidies is proportionally greater, H receives more firms. This is due to the fact that the reduction in tariffs has been more than offset by the fall in ρ_X^*, so that although H has reduced its import tariffs, paradoxically its market is now more protected (it is of more difficult access for the products of F) because the reduction in the export subsidies of F has been proportionately greater than the import tariff reduction of H. In short, the ultimate result of changes occurring in the import infrastructure of a country depends on the magnitude of the reaction of the other country. This reaction refers to the export infrastructure of F, given that both types of infrastructure, of imports of H and exports of F, are functionally linked.

Improvements in transport infrastructure also have an undetermined effect on the number of firms.

PROPOSITION 7. *In the simplified case of countries with the same endowment of factors* ($K = K^*$ *and* $L = L^*$) *and when* $\rho_D \neq \rho_D^*$, $\frac{\partial n}{\partial \rho_C} \succ 0$ *as long as* $\frac{\rho_D}{\rho_X^*(\rho_M)\rho_M\rho_C} \succ \frac{\rho_D^*}{\rho_X(\rho_M^*)\rho_M\rho_C}$.

Hence, an investment in transport infrastructure appears capable of attracting firms as long as the country which carries out the investment maintains a more favourable ratio between the cost of domestic trade and the overall cost of importation than the other country. That is, the lower the cost of domestic transport (greater ρ_D for H) and/or the higher the cost of importation (lower $\rho_X^*(\rho_M)\rho_M\rho_C$ for H), the easier it will be for investment in transport infrastructure to attract firms. Thus, if a firm locates in H as a consequence of the region having improved its transport infrastructure, it obtains, in relative terms, good access to the domestic market at the same time as being protected from imports from the other country, so that it ensures the demand the firm is facing.

In the Martin and Rogers model we could deduce that an improvement in international infrastructure has negative effects for a country if this has worse domestic infrastructure (for the case when the two countries have equal factor endowments). In our case the direction of influence of ρ_X, ρ_M and ρ_C can be different, and consequently this fact explains why the effect of international infrastructure in Martin and Rogers results undetermined. It should be kept in mind that in the Martin and Rogers model, the international infrastructure is unique, without distinguishing between its components ρ_X, ρ_M and ρ_C and so the distinct effects of these components are superimposed, in such a way that the final direction of the influence is undetermined.

Let us now imagine (as in Martin and Rogers) that infrastructure investment is financed through a fixed tax T on incomes of residents in H, and c units of the numeraire are necessary to raise the level of infrastructure one unit. At the same time g_j $(j = D, X, M, C)$ represents the adjusted degree of quality of the corresponding infrastructure, where $\tau_j = \tau_j(g_D)$.

$$\frac{\partial n}{\partial g_D} = \frac{\sigma - \alpha}{\sigma} \frac{K + K^*}{L + L^*}$$
$$\left[\frac{-c\rho_D^* L}{\left(\rho_D^* - \rho_X\left(\rho_M^*\right)\rho_M^*\rho_C\right)} + \frac{\rho_X^*\left(\rho_M\right)\rho_M\rho_C L^* I^*}{\left(\rho_D - \rho_X^*\left(\rho_M\right)\rho_M\rho_C\right)^2} \frac{\partial \rho_D}{\partial g_D} \right] \qquad [20]$$

The sign of this derivative is undetermined. The first term inside the brackets is negative; it shows the negative effect on attracting firms caused by the decline in income following the tax. The second term is positive and represents the favourable effect (see [19]) that the improvement in domestic infrastructure has on the number of firms in H. The positive component is more likely to predominate if this investment is efficient ($\partial\rho_D/\partial g_D$ "large"), if $\rho_X^*(\rho_M)$ is "high" and ρ_D is "small". The explanation of the influence of ρ_X^* and ρ_D is as follows: if the level of domestic infrastructure in H is low and the international export infrastructure in F is high, then, according to [19], the number of firms in F will tend to be much higher than the number of firms in H, so the potential possibility of H raising the number of firms is strong.

Let us now see what happens if H finances international export infrastructure. The sign of the derivative in this case is undetermined. We could obtain, for their part, $\partial n/\partial g_M$ and $\partial n/\partial g_C$. This is not necessary because we can see that these derivatives will not have a determined sign. Effectively, according to [19], the effects of these types of infrastructures (international import and transport) on n is undetermined, to which we must add a negative addend which is the decrease in I caused by the tax, so that the sign of the global result will continue to be undetermined.

In summary, if financing is external and the country wants to attract economic activity, it has incentives to improve its domestic and export infrastructures. If self-financed, it is more likely that the effects turn out to be indeterminate. In the cases of co-financing, it is more likely that the consequences are positive, the lower the portion financed by the country in question is. All these conclusions are valid for the cases in which the regions are of the same or different size.

It remains for us to analyse welfare in the different infrastructure investment policies. The indirect function of utility of a representative consumer of H for the general case $(K \neq K^*, L \neq L^*, \rho_D \neq \rho_D^*)$ is given by:

$$V = \left(\frac{\sigma-1}{\sigma\beta}\right)^{\alpha} I^{*\frac{\sigma-1+\alpha}{\sigma-1}} \left[\frac{L^*(K+K^*)(\sigma-\alpha)}{(L+L^*)\sigma}\right]^{\frac{\alpha}{\sigma-1}} \left(\frac{\rho_D\rho_D^* - \rho_X(\rho_M^*)\rho_M^*\rho_X^*(\rho_M)\rho_M\rho_C^2}{\rho_D^* - \rho_X(\rho_M^*)\rho_M^*\rho_C}\right)^{\frac{\alpha}{\sigma-1}}$$

$$= Q\left(\frac{\rho_D\rho_D^* - \rho_X(\rho_M^*)\rho_M^*\rho_X^*(\rho_M)\rho_M\rho_C^2}{\rho_D^* - \rho_X(\rho_M^*)\rho_M^*\rho_C}\right)^{\frac{\alpha}{\sigma-1}} \qquad [21]$$

The signs of the corresponding derivatives are:

$$\frac{\partial V}{\partial \rho_D} \succ 0 \qquad \frac{\partial V}{\partial \rho_X} \succ 0 \qquad \frac{\partial V}{\partial \rho_M} ?0 \qquad \frac{\partial V}{\partial \rho_C} ?0 \qquad [22]$$

Regional policies that improve domestic and export infrastructure increase welfare, while those dedicated to import and transport infrastructure do not have a clear effect. These are the same results as those relative to the number of firms, so public policies that attract firms also increase welfare, while those that have an undetermined effect on the number of firms have the same effect on welfare. Thus, there is a direct relationship between the level of economic activity (number of industrial firms) and the welfare of the individuals (see propositions 6 and 8 and 7 and 9).

First, we analyse the welfare effects of the parameter ρ_M.

PROPOSITION 8. *In the general case* $(K \neq K^*, L \neq L^*, \rho_D \neq \rho_D^*)$ *the necessary and sufficient condition for an improvement in infrastructure to increase welfare is the same that make it possible to increase the number of the country's firms. Hence:*

$\frac{\partial V}{\partial \rho_M} \succ 0$ *if and only if* $E_{\rho_X^*} \succ 1$

having already defined $E_{\rho_X^*}$.

Improvements in transport infrastructure also have an undetermined effect on welfare.

PROPOSITION 9. *In the simplified case of countries with the same endowment of factors* ($K = K^*$ *and* $L = L^*$) *and when* $\rho_D \neq \rho_D^*$, $\frac{\partial V}{\partial \rho_C} \succ 0$ *as long as* $\frac{\rho_D}{\rho_X^*(\rho_M)\rho_M\rho_C} \succ \frac{\rho_D^*}{\rho_X(\rho_M^*)\rho_M^*\rho_C}$.

As such, this result concurs with the effects the different infrastructures have on firm movements. Thus, as would appear logical, an infrastructure policy that has positive consequences on the number of firms is also positive for welfare. This conclusion differs from Martin and Rogers, where any increase in the quality of infrastructure, whatever its effect on the number of firms in the country, produces growth in welfare[6]. In our case, by distinguishing between international import, export and transport infrastructures, it is possible to distinguish the different effects these infrastructures have on welfare. This aspect is not present in Martin and Rogers. This is the first contribution of our work. The second contribution lies in the different effects that different types of infrastructures exert on industrial activity: domestic and international export infrastructures attract firms, while those of transport and international import do not have a clear effect. These divergencies in behaviour cannot be considered in the Martin and Rogers model and, in this sense, our model extends Martin and Rogers. This latter model now remains as a particular case of the model presented in this paper.

[6]It can be demonstrated that this is only true if $K = K^*$ and $L = L^*$. Otherwise $\partial V/\partial \rho_D > 0$, but the sign of $\partial V/\partial \rho_I$ is undetermined, with ρ_I being the parameter that represents the level of international infrastructure.

5. Conclusions

The objective of this paper is to analyse how different types of infrastructure affect the location decisions of firms. Extending Martin and Rogers (1995), we look at a range of arguments regarding the classes of infrastructure which a region can possess: domestic, international transport, international export and international import infrastructure. We also assume that the export infrastructure of one country depends on the import infrastructure of another. Infrastructures are modelled as iceberg type transport costs. This facilitates our analysis of their effects on firm and consumer location.

The literature referring to transport costs-infrastructure finds that such costs affect the spatial configuration of equilibrium in different ways (see Krugman, 1991, Krugman and Venables, 1995, Venables, 1996, Puga, 1999 and Alonso-Villar, 2001). In the pioneering work of Krugman (1991), reductions in transport costs favour industrial agglomeration, while in Alonso-Villar (2001) the same reductions make concentration more difficult to achieve. Krugman and Venables (1995), Venables (1996) and Puga (1999) find a non-monotonous relationship between the degree of agglomeration and the magnitude of transport costs, so that if transport costs fall below a certain limit there are motives to produce a concentration of manufacturing activity; if they continue to fall they reach a point below which dispersion is obtained. Obviously, these are not comparable results as they are deduced from different models, departing from different hypotheses and a different emphasis. Nonetheless, they demonstrate that taking a single parameter as representative of the transport costs-infrastructure can be leaving unrevealed behaviour that is not reducible to a single pattern. To capture these potentially different patterns, it is necessary to introduce in the model various parameters which take into account the wide concept of transport costs- infrastructures.

Then, it is reasonable to consider the entire taxonomy of transport costs-infrastructure. By doing so, and as our results confirm, one can know the different effects they provoke on firm location.

Martin and Rogers (1995) find that domestic infrastructure attracts industrial activity while an improvement in international infrastructure only brings firms to a country that already possesses a better domestic infrastructure; furthermore, they deduce that any investment in infrastructures, whatever its effect on the number of firms, increases welfare. Our results complete and fine-tune those of martin and Rogers. We show that the optimum regional policy for an area that is interested in attracting industrial activity involves improving its domestic and international export infrastructures; investment in transport or international import infrastructures, meanwhile, does not have a clear effect. What about welfare? If an investment in infrastructures attracts firms (domestic and international export infrastructures) welfare also increases, whereas if the effect of the investment in infrastructures is undetermined (transport and international import infrastructures), the consequences for welfare are also undetermined

What explanation can we find for the fact that export and domestic infrastructures attract industry? In contrast to import and transport infrastructure, both unequivocally increase the demand for firms located in that country. Better access to the markets for products and to consumers constitutes, in the presence of transport costs, a 'backward linkage'. Firms locate wherever demand is greatest, but demand is greater where there are already other firms, as these firms are associated with the manufacturing workers and their families. This is the type of circular causation habitual in New Economic Geography models.

Finally, we want to mention an extension of the work we present here which appears genuinely interesting. The role of the state is susceptible to more appropriate treatment, reflecting in a more explicit way the aspect of obtaining resources used in financing public infrastructure. Without doubt, the study of the effects of state intervention on the spatial configuration of the resulting equilibrium is one of the most promising areas of research in this field (see Baldwin et al., 2003). The governments' role as a potential corrector of regional imbalances demands more in-depth exploration in this type of theoretical analysis.

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Resumen

En este trabajo se analiza si distintos tipos de infraestructura afectan a las decisiones de localización de los agentes económicos. Para ello a partir del modelo de Martin y Rogers (1995) se considera la casuística completa en cuanto a las clases de infraestructuras que puede poseer una región: domésticas, internacionales de transporte, internacionales de exportación e infraestructuras internacionales de importación. El resultado principal es que la política regional óptima para que una zona atraiga actividad industrial pasa por mejorar sus infraestructuras domésticas e internacionales de exportación. Superiores infraestructuras domésticas y de exportación también incrementan el bienestar.

Palabras clave: infraestructuras públicas, localización industrial.

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