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Industrial location and public infrastructure

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Abstract

This paper examines the impact of public infrastructure on industrial location when increasing returns are present. Trade integration implies that firms tend to locate in countries with better domestic infrastructure. High levels of international infrastructure and strong returns to scale magnify industrial relocation due to differentials in domestic infrastructure or capital endowments. Regional policies which finance domestic infrastructure in a poor country lead firms to relocate in this country. Regional policies which finance international infrastructure in a poor country will lead firms to leave this country. We also analyze the incentives for countries to inhibit industrial relocation.

Key words: Public infrastructure; Industrial location; Trade integration; Regional policies

JEL classification: F1; H4; R3

1. Introduction

In the past few years, many new important infrastructure projects have been developed in Europe: the Channel Tunnel, the high speed rail network, new transalpine base tunnels, new telecommunications networks,

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EC-funded infrastructure projects in the poorest regions and 'soft infrastructure' such as basic research, training networks and education infrastructure. One cannot fail to notice that this new interest of European governments in infrastructure coincides with a new wave of trade integration marked by the building of the internal market and the Maastricht treaty. The changes in Eastern Europe have also revealed that one important obstacle to the integration of these countries in the world economy is the very poor state of their infrastructure.

Recent closed-economy models of public infrastructure for example Arrow and Kurz, 1970; Barro, 1990 have stressed the substitutability of public infrastructure and private capital in the production function. These models cannot easily be adapted to analysis of regional integration: putting government capital into the production function fails to capture the role infrastructure plays in facilitating trade between countries.

Regional scientists (see for example Christaller, 1933; Lösch, 1940; Isard, 1956; Biehl, 1986; Vickerman, 1989, 1990) and economic historians (see for example Chinitz, 1960) have long studied the role of public infrastructure in regional development and in the process of industrial concentration. As emphasized by Krugman (1993), these studies suggest interesting directions of research that economists can build upon. This paper places itself in the spirit of Krugman's research agenda of combining the modeling approach developed by trade theorists with the intuitive approach of the regional science tradition.

We propose a new way to model different types of public infrastructure, which allows us to analyze its impact on trade patterns, industrial location, and welfare. We interpret public infrastructure in a broad sense as comprising any facility, good, or institution provided by the state which facilitates the juncture between production and consumption. Under this interpretation, not only transport and telecommunications but also such things as law and order qualify as public infrastructure. Poor infrastructure imposes costs on trade within and between countries, so that our model differs from Krugman's modeling of transport costs, which only affect international trade. In our model, these costs take the 'iceberg' form invented by Samuelson (1954): if infrastructure is poor, then a large portion of the goods produced and traded will not actually be consumed by the national or foreign purchaser. We differentiate between infrastructure that facilitates domestic trade (domestic infrastructure) and infrastructure that facilitates international trade (international infrastructure).

The first conclusion of this paper is that firms of the increasing returns sector will tend to locate in countries with the best domestic infrastructure when trade is integrated, in order to take advantage of economies of scale. Better domestic infrastructure implies a lower price and a higher relative

demand for the goods produced in these countries. Differentials in domestic infrastructure determine the direction of relocation after trade integration. Levels of international infrastructure influence the sensitivity of industrial location to differentials in domestic infrastructure.

We also find that infrastructure interacts in an interesting way with the other determinants of industrial location examined in the economic geography literature Krugman, 1991; Krugman and Venables, 1990; Bertola, 1992. In general, a higher level of international infrastructure will magnify concentration effects of differentials in domestic infrastructure. Another contribution of the paper is the introduction of capital in the economic geography model. It enables us to study how infrastructure and the distribution of capital endowments interact to determine industrial location.

These results have important policy implications. In Europe, the EC Commission views the wide regional disparities in infrastructure both at the national level and between EC countries (see Biehl, 1986) as a major impediment to real convergence. Because of this concern, the EC regional policies (the structural funds and the new cohesion funds created by the Maastricht Treaty) are mostly used to finance new infrastructure in transport, telecommunications, education, and energy in the poorest regions. For the coming years, these transfers will amount to around 5% of GDP for countries such as Greece and Portugal (see Commission of the European Communities, 1992, and Martin and Rogers, 1994, for a more detailed description of the E.C. regional policies). In our model, if the aim of a regional aid policy is to foster industrial convergence between a rich and a poor country, then the policy must be biased in favor of facilitating domestic rather than international trade. A regional policy of financing domestic infrastructure will always bring industrial relocation to this region. However, a regional aid program that improves international infrastructure in the poor country brings more rather than less industrial concentration, and may therefore contribute to regional divergence.

Finally, a country with poor infrastructure may want to restrict industrial location that follows trade integration, since the higher cost of goods produced outside the country because of relocation dominates the income effect for capital owners who can benefit from investment in the good infrastructure country. We find that incentives to restrict relocation of firms will be greater the stronger the economies of scale and the better the infrastructure in the two countries.

Section 2 presents the model. Section 3 finds the free-trade equilibrium, derives the relocation impact of trade integration, and analyzes the determinants of industrial concentration. Section 4 derives policy implications for public infrastructure policies and for policies that restrict relocation of firms. Section 5, concludes and suggests some extensions of the model.

2. The model

The model is a variant of Helpman and Krugman (1985) and Krugman (1991). There are two countries. In each country, a representative consumer chooses from a menu of goods to maximize the utility function:

$$U = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} D^{\alpha} Y^{1-\alpha} . \tag{1}$$

Y will be the numeraire good and D a composite good made up of a number of differentiated products:

$$D = \left[\sum_{i=1}^{N} D_i^{1-1/\sigma} \right]^{1/(1-1/\sigma)}, \sigma > 1 . \tag{2}$$

N is the total number of differentiated goods produced at home and abroad. This total will turn out to be fixed by initial endowments of capital, but the location of firms will be determined in equilibrium.

A typical home consumer chooses D_i and Y to maximize (1) subject to the budget constraint:

$$\sum_{i=1}^{n} \tau_D p_i D_i + \sum_{j=n+1}^{N} \tau_I \tau_I^* p_j^* D_j + Y = I . \tag{3}$$

An asterisk refers to the foreign country. $N = n + n^*$, where n and n^* are the respective numbers of differentiated goods produced in the home country and the foreign country.

We have allowed in Eq. (3) for 'transit' costs in Samuelson's iceberg form, so that some of each of the differentiated goods melts away in transit: only $1/\tau_D < 1$ of purchases of any home good, and $1/\tau_I \tau_I^* < 1$ of a foreign good, are available for consumption. A purchase of a foreign good incurs a cost τ_I^* in getting out of the foreign country, and τ_I in its reaching its destination at home. These costs affect the foreign country symmetrically: in the foreign country, $1/\tau_D^*$ of purchases of a domestically-produced good, and $1/\tau_I \tau_I^*$ of an imported good, are consumable. We assume that $\tau_D < \tau_I \tau_I^*$ and $\tau_D^* < \tau_I \tau_I^*$: infrastructure costs are lower when the good is produced at home than if produced abroad, that is, when it has to incur both the home and the foreign infrastructure costs.

We interpret these costs as directly related to the quality of countries' infrastructures and public services: τ_D, τ_D^*, τ_I, and τ_I^* are the infrastructure costs of, respectively, domestic trade in the home country, domestic trade in the foreign country, international trade in the home country, and international trade in the foreign country. Changes in these costs represent changes in infrastructure. A reduction in τ_D, for example, is an improvement in the

home country's domestic infrastructure. Formally, if g_D is the quality-adjusted level of domestic infrastructure, then:

$$\tau_D = \tau_D(g_D); \frac{\partial \tau_D}{\partial g_D} < 0 \tag{4}$$

and similarly for international infrastructure.

This way of modeling public infrastructure departs from earlier models, such as Arrow and Kurz (1970) and Barro (1990) in which infrastructure is an input in the production function. These models cannot address the role played by infrastructure in regional integration because they do not capture the function of infrastructure in facilitating trade within and between countries. In our model, infrastructure intervenes in the relation between the firm and the consumer and therefore its main impact will be through demand. However, as in earlier models, we assume that public infrastructure can only be supplied by the government. This simplifying assumption captures the consequences of difficult implementation of user charges for non-excludable services or under-provision by private producers in the presence of external effects.

Our characterization of public infrastructure as affecting the amount of output that actually reaches the consumer captures a key role played not only by transport but also by other types of infrastructure. If law and contract enforcement of telecommunication networks are weak, for example, this will also divert real output from consumption. Similarly, general public administration, in particular tax collection agencies and local administration, can impose distortive costs on the economy that can be modeled as 'iceberg' costs on consumption. In the context of our model these types of infrastructures, as well as transport infrastructure that facilitates domestic trade, can be classified as domestic infrastructures. On the other hand, the building of a harbor or of an international airport, or the improvement of the trade administration or of the international telecommunication system would be interpreted as improvements of international infrastructure. In all these cases, both imports and exports are facilitated. We do not distinguish between 'export' infrastructure and 'import' infrastructure because it is difficult to think of many types of infrastructures that would facilitate exports but not imports and vice versa. The main distinction we make in the model is between domestic infrastructure and international infrastructure. Because we want to focus on the role of infrastructure in facilitating transactions, we assume that neither domestic nor international infrastructures affect the production function.

As in Helpman and Krugman (1985) and Krugman (1991), good Y is introduced to tie down the wage rate in each country. We rule out infrastructure costs on this good. If we include these costs in the model,

countries will consume only domestically-produced amounts of Y. In general, both labor markets then will not be in equilibrium.

In contrast to Krugman (1991), there is a fixed capital requirement for each differentiated good, and labor is internationally immobile and intersectorally mobile. The differentiated products are produced with identical technologies that use two factors of production, capital and labor. One unit of capital is required to produce one variety of good. Thus, the total number of varieties is fixed through the endowment of capital. There are K units of capital in the home country and K^* units in the foreign country. Each good also has a unit labor cost of β. The choice of p_i that maximizes profits obeys the standard rule in monopolistic competition: $p_i = w\omega\sigma/(\sigma - 1)$. In equilibrium, $w\sigma/(\sigma - 1)$ is the ratio of average cost to marginal cost. Therefore, as in Krugman (1991), σ can be interpreted as an inverse index of equilibrium economies of scale.

Rents to capital equal the difference between revenues and labor costs:

$$r = p_i x_i(p_i) - w\beta x_i(p_i) = \frac{w\beta x}{\sigma - 1}. \tag{5}$$

Good Y is produced under constant returns to scale, using only labor as an input. It takes one unit of labor to produce one unit of Y. Since Y is the numeraire, profit maximization implies that $w = 1$. A consumer supplies one unit of labor inelastically, and owns K/L units of capital, so individual income is: $I = 1 + rK/L$, where L is total population of the home country.

Solving the first order conditions for the consumers, we find that consumer demands are:

$$D_i = \frac{\sigma - 1}{\beta\sigma} \frac{\rho_D \alpha I}{\tau_D(n\rho_D + n^*\rho_I\rho_I^*)}, \tag{6a}$$

$$D_i = \frac{\sigma - 1}{\beta\sigma} \frac{\rho_I \rho_I^* \alpha I}{\tau_I \tau_I^*(n\rho_D + n^*\rho_I\rho_I^*)}, \tag{6b}$$

$$Y = (1 - \alpha)I, \tag{6c}$$

where $\rho_D = \tau_D^{1-\sigma}$, and ρ_D^*, ρ_I, and ρ_I^* are defined analogously. Since σ and τ_D are more than 1, ρ_D is between 0 and 1. A higher ρ_D indicates a better domestic infrastructure in the home country.

3. The equilibrium location of firms

To analyze the relocation impact of trade integration, we compare the location of firms in the autarky equilibrium to the equilibrium with free trade and free movement of capital. In autarky, industrial location is

entirely determined by capital endowments: there are K firms in the home country and K^* in the foreign country.

When trade and capital flows are unrestricted[1], the ownership of initial K and K^* will not change but the physical location of capital will. Four equilibrium conditions determine firm size (x, x^*) and location (n, n^*). First, when differentiated goods are produced in both countries, demands (inclusive of infrastructure costs) must equal supplies at home and abroad:

$$x = \frac{\sigma - 1}{\beta\sigma}\left(\frac{\alpha L I \rho_D}{n\rho_D + n^*\rho_I\rho_I^*} + \frac{\alpha L^* I^* \rho_I \rho_I^*}{n^*\rho_D^* + n\rho_I\rho_I^*}\right), \tag{7a}$$

$$x^* = \frac{\sigma - 1}{\beta\sigma}\left(\frac{\alpha L^* I^* \rho_D^*}{n^*\rho_D^* + n\rho_I\rho_I^*} + \frac{\alpha L I \rho_I \rho_I^*}{n\rho_D + n^*\rho_I\rho_I^*}\right). \tag{7b}$$

Next, when capital flows are unrestricted, neither country can offer a higher rent to capital. In equilibrium, when n and n^* are positive, rents to capital must be equalized, which implies:

$$x = x^*. \tag{7c}$$

Finally, the total number of firms is fixed by the capital endowment, so:

$$n + n^* = K + K^*. \tag{7d}$$

Eqs. (7a)–(7d) determine x, x^*, n and n^*. Firm output is:

$$x = x^* = \frac{\alpha(\sigma - 1)}{\beta(\sigma - \alpha)}\frac{L + L^*}{K + K^*}. \tag{8}$$

The scale of each firm, x, is inversely related to the worldwide capital labor ratio and does not depend on infrastructure.

The numbers of firms in each country are[2]:

$$n = \frac{\sigma - \alpha}{\sigma}\frac{K + K^*}{L + L^*}\left[\frac{L I \rho_D^*}{\rho_D^* - \rho_I\rho_I^*} - \frac{L^* I^* \rho_I \rho_I^*}{\rho_D - \rho_I\rho_I^*}\right], \tag{9a}$$

$$n^* = \frac{\sigma - \alpha}{\sigma}\frac{K + K^*}{L + L^*}\left[\frac{L^* I^* \rho_D}{\rho_D - \rho_I\rho_I^*} - \frac{L I \rho_I \rho_I^*}{\rho_D^* - \rho_I\rho_I^*}\right], \tag{9b}$$

where:

[1] In practice, it takes time to reinstall capital in a new location and firms may face relocation costs. Relocation costs can be affected by restrictions to capital mobility between countries. We take this up in Section 4.2.

[2] We abstract from the integer problem and treat the number of firms as a continuous variable.

$$I = 1 + \frac{\alpha}{\sigma - \alpha}\left(\frac{L + L^*}{K + K^*}\right)\frac{K}{L}, \tag{10a}$$

$$I^* = 1 + \frac{\alpha}{\sigma - \alpha}\left(\frac{L + L^*}{K + K^*}\right)\frac{K^*}{L^*}, \tag{10b}$$

Since capital ownership is fixed and labor is immobile, no agglomeration force is set into motion when firms relocate. Movements of capital from the foreign to the home country lower $x - x^*$, and reduce the incentive for further movement. Therefore, this equilibrium location is stable.

We can now examine the factors that influence the equilibrium location of firms when trade is integrated: firms locate in countries with better domestic infrastructure, high incomes and large markets.

Suppose first that countries differ only in their infrastructure and that the home country has a lower quality of domestic infrastructure than the foreign country ($\rho_D < \rho_D^*$). Then, the equilibrium difference in the number of firms between the rich (foreign) and the poor (home) country is equal to twice the transfer of capital from the poor infrastructure country to the rich infrastructure country:

$$n^* - n = 2(K - n) = 2K\frac{\rho_I\rho_I^*(\rho_D^* - \rho_D)}{(\rho_D - \rho_I\rho_I^*)(\rho_D^* - \rho_I\rho_I^*)}. \tag{11}$$

This equation shows that trade integration will lead firms to locate in countries with good domestic infrastructure. A lower ρ_D (a higher τ_D) will increase the price of the home differentiated goods for domestic consumers and will therefore decrease the demand for these goods and increase the demand for foreign goods. To take advantage of the higher demand in the country with better domestic infrastructure and therefore of the returns to scale, firms will locate in this country. Note that differentials in international infrastructures alone will not imply industrial relocation. However, good international infrastructure will increase the sensitivity of industrial location to differentials in domestic infrastructure. At high levels of ρ_I and ρ_I^*, even small differences in domestic infrastructure will drive a large number of firms to relocate in the best infrastructure country.

In the extreme case of full concentration (for example, $n^* = K + K^*$ and $n = 0$) it may be that the poor infrastructure country entirely specializes in constant returns-to-scale goods (for good Y to be produced in both countries it must be that: $\sigma(1 - \alpha) \geq \alpha(\sigma - 1)$). This will be so if:

$$\frac{\rho_D^*(\rho_D - \rho_I\rho_I^*)}{\rho_I\rho_I^*(\rho_D^* - \rho_I\rho_I^*)} < 1.$$

This inequality shows that full concentration is likely to occur if the difference in domestic infrastructures is important and if international

infrastructures are strong. This result mirrors Krugman's (1991) finding that if transport costs are low and economies of scale are strong, manufacturing will concentrate in one country.

Next, suppose that countries differ only in their capital endowments (i.e. $\rho_D = \rho_D^*$, $\rho_I = \rho_I^*$ and $L = L^*$). In this case, the transfer of capital from the home country to the foreign country is:

$$K - n = \frac{n^* - n}{2} - \frac{K^* - K}{2} = \frac{K^* - K}{2}\left(\frac{\alpha}{\sigma}\frac{\rho_D + \rho_I^2}{\rho_D - \rho_I^2} - 1\right). \tag{12}$$

Capital will flow to the country with the higher capital endowment if the bracketed term in Eq. (12) is positive. Differentials in capital endowments have two effects with opposite implications for firm location. On the one hand, a country with a lower capital endowment produces fewer differentiated products. This makes the country an attractive location for firms, because competition is less stringent and therefore the scale of production is larger for each variety. On the other hand, this country will have a lower income and therefore a smaller demand for differentiated goods, making it a less attractive location for firms. This second effect will dominate the first effect if returns to scale are strong (σ is low), if the share of differentiated goods, α, is high, and if international infrastructures are strong. In this case, a country that is initially rich in capital will attract more capital. Note that even though trade integration might have induced capital movements from the rich to the poor country, the country with a high capital endowment will still have more firms than the country with a low capital endowment:

$$n^* - n = \frac{\alpha}{\sigma}\frac{\rho_D + \rho_I^2}{\rho_D - \rho_I^2}(K^* - K). \tag{13}$$

As in the previous example, good international infrastructures magnify the concentration effects of differentials in capital endowments. This result is supported empirically by Wheeler and Mody (1992). They find that the magnitude of investment response to a particular country characteristic (infrastructure, labor cost, foreign investment, industrialization and market size) varies considerably with the level of development. The elasticities of factors determining location of firms in the electronics industry and in manufacturing are generally higher in high-income countries than in low-income countries. Low levels of international infrastructure imply that firms will wish to be close to their markets and will not concentrate in one country. This suggests that regional integration between countries with poor infrastructure (for example developing countries) will imply less economic dislocation than between countries with strong infrastructure (developed countries).

Finally, suppose countries differ only in their market size (i.e. $\rho_D = \rho_D^*$,

$\rho_I = \rho_I^*$ and $K = K^*$). Firms then will tend to locate in countries with the largest markets. This effect is similar to the market size effect in Krugman (1991).

4. Infrastructure, welfare and policy implications

Our model of infrastructure has implications for two issues that currently are of importance. First, what are the consequences of improving infrastructure for trade, industrial location, regional convergence and welfare? Second, what are the incentives to inhibit relocation of firms?

4.1. Improvements in infrastructure

This model can be used to ask what effect a policy that improves domestic infrastructure will have on industrial location. However, when considering the impact of such a policy, we cannot ignore its cost, since the financing of infrastructure may also affect industry location. Until now, we have treated the government capital stock, g_D, and its associated infrastructure costs, $\tau_D(g_D)$, as exogenous. We now will assume that any improvement in domestic infrastructure is financed by an increase in a lump sum tax T imposed on incomes of resident agents (as the focus of the paper is on infrastructure and not tax policies, we do not consider more complex financing schemes, such as taxes on profits, incomes, consumption or imports). Suppose that one unit of infrastructure costs c units of the numeraire good: $c\,\mathrm{d}g = \mathrm{d}T = -\mathrm{d}I$ and $\partial I/\partial g_D = c\,\partial I/\partial T = -c$. The net relocation effects of a tax-financed improvement in domestic infrastructure are given by:

$$\frac{\partial n}{\partial g_D} = -\frac{\partial n^*}{\partial g_D} = \frac{\sigma - \alpha}{\sigma}\frac{K + K^*}{L + L^*}\left(-\frac{cL\rho_D^*}{\rho_D^* - \rho_I\rho_I^*} + \frac{L^*I^*\rho_I\rho_I^*}{(\rho_D - \rho_I\rho_I^*)^2}\frac{\partial \rho_D}{\partial g_D}\right), \tag{14}$$

where the first element in the bracket is the negative effect of taxes on income and the second element is the positive effect of an improvement in domestic infrastructure. Since $\rho_D = \tau_D^{1-\sigma}$, $\partial\rho_D/\partial g_D = (1-\sigma)\tau_D^{-\sigma}\,\partial\tau_D/\partial g_D < 0$. An improvement in domestic infrastructure in the home country will imply a relocation of firms to this country, if the effect of the increase in demand for home goods due to this improvement is larger than the effect of the decrease in demand due to the increase in taxes. This will be the case, in particular, if the increase in government expenditures has a large effect on

domestic infrastructure costs as measured by $\partial\tau_D/\partial g_D$, that is if the productivity of government expenditures is high.

When the improvement of domestic infrastructure is paid for by another region or country (a third party), such as in the case of EC regional aid or foreign aid, the income effect of financing the improvement in domestic infrastructure will not exist. Therefore, the direction of the relocation will be unambiguous. In this case, a regional policy financing domestic infrastructure in a poor region will always bring firms to the region.

The effectiveness of a regional aid policy of improving domestic infrastructure is higher, the better is international infrastructure: the second term of the bracket in Eq. (14) increases with ρ_I and ρ_I^*. This is because, as we saw in Section 3, good international infrastructure and strong economies of scale magnify the sensitivity of industrial location to changes in domestic infrastructure (and to any factor that determines industrial location). If domestic infrastructure improves in a poor country thanks to a regional policy, foreign firms will move to this country because of the higher demand. Industries will relocate more easily to take advantage of new infrastructure conditions if international infrastructures are strong.

The consequences of a regional policy which improves international infrastructure in a country are very different from the consequences of improving domestic infrastructure. In fact, improving international trade infrastructure in a country which has an overall low quality of domestic infrastructure will lead firms to relocate outside this country. Assume for simplicity that the two countries are identical in market size ($L = L^*$) and in capital endowments ($K = K^*$). The relocation effect of improving international infrastructure (financed by a third party) in the home country is:

$$\frac{\partial n}{\partial \rho_I} = K \frac{\rho_I^*(\rho_D - \rho_D^*)(\rho_D\rho_D^* - \rho_I^2\rho_I^{*2})}{(\rho_D - \rho_I\rho_I^*)^2(\rho_D^* - \rho_I\rho_I^*)^2}$$

$$= \frac{n - n^*}{2} \frac{\rho_D\rho_D^* - \rho_I^2\rho_I^{*2}}{\rho_I(\rho_D - \rho_I\rho_I^*)(\rho_D^* - \rho_I\rho_I^*)} \tag{15}$$

which is negative if $\rho_D < \rho_D^*$, that is, if n is initially lower than n^*. Hence, a regional policy which improves international infrastructure in a country with poor domestic infrastructure will lead firms to relocate outside the country.

When international infrastructure costs are lowered, trade between countries is facilitated. Firms will then be able to take advantage of even very slight differences in the economic characteristics of countries to concentrate in the country with highest demand and will not need anymore to locate close to all their consumers. They will do so in particular when returns to scale are important so that the incentive to relocate where demand is higher is large. Although we have illustrated this result when the

difference between the two countries arose because of their domestic infrastructure, it can also be shown that a regional policy can lead to industrial concentration when the driving force behind industrial relocation is based on differentials in market size or capital endowments, i.e. regional incomes.

The policy implication is clear. If the aim of an infrastructure policy is to foster industrial convergence between a rich and a poor country, then the policy must be biased in favor of infrastructure that facilitates intra-regional or domestic trade rather than international trade. In the first case, the higher domestic demand induced for the goods produced in the poor country will lead firms to relocate in this country. Hence, such a policy will foster industrial convergence. In the second case, the facilitation of international trade amplifies the disadvantage of the poor country and may lead to further industrial divergence.

What are the welfare implications of these two types of regional policies for the country which receives the regional aid? The indirect utility level of an agent in the home country is:

$$V = \left(\frac{\sigma - 1}{\beta\sigma}\right)^{\alpha} I(n\rho_{\mathrm{D}} + n^{*}\rho_{\mathrm{I}}\rho_{\mathrm{I}}^{*})^{\frac{\alpha}{\sigma-1}}. \tag{16}$$

Substituting for the equilibrium location of firms and assuming for simplicity that the two countries are identical except for infrastructure, and that there are a positive number of increasing returns-to-scale goods produced in each country, the indirect utility of an agent in the home country is:

$$V = \left(\frac{\sigma - 1}{\beta\sigma}\right)^{\alpha} I\left(K\frac{\rho_{\mathrm{D}}\rho_{\mathrm{D}}^{*} - \rho_{\mathrm{I}}^{2}\rho_{\mathrm{I}}^{*2}}{\rho_{\mathrm{D}}^{*} - \rho_{\mathrm{I}}\rho_{\mathrm{I}}^{*}}\right)^{\frac{\alpha}{\sigma-1}}. \tag{17}$$

$\partial V/\partial\rho_{\mathrm{D}} > 0$: a regional policy that finances domestic infrastructure improves the welfare of the country which receives such transfers by making more of its home-produced goods available for consumption. It also causes firms to relocate to this country. Home consumers benefit from this relocation, because they pay only the domestic infrastructure cost on these new goods produced at home rather than both international infrastructure costs, as when the goods are produced in the foreign country.

The welfare implication of a regional policy that finances international infrastructure in the home country is for home agents:

$$\frac{\partial V}{\partial\rho_{\mathrm{I}}} = \frac{\alpha}{\sigma - 1} V \frac{\rho_{\mathrm{I}}^{*}(\rho_{\mathrm{D}}\rho_{\mathrm{D}}^{*} - 2\rho_{\mathrm{D}}^{*}\rho_{\mathrm{I}}\rho_{\mathrm{I}}^{*} + \rho_{\mathrm{I}}^{2}\rho_{\mathrm{I}}^{*2})}{(\rho_{\mathrm{D}}^{*} - \rho_{\mathrm{I}}\rho_{\mathrm{I}}^{*})(\rho_{\mathrm{D}}\rho_{\mathrm{D}}^{*} - \rho_{\mathrm{I}}^{2}\rho_{\mathrm{I}}^{*2})}. \tag{18}$$

This is unambiguously positive as the term in parenthesis in the numerator is positive if there are increasing returns-to-scale firms in both countries. There are two effects of this regional policy. First, better international infra-

structure will induce relocation of firms to the country which has an initial advantage in domestic infrastructure. This implies that consumers of the poor country will have to bear higher infrastructure costs on the goods now produced in the rich country. Second, it also lowers the cost of all goods imported from the rich country. This second effect always dominates the first one. This is because the condition for no full concentration limits the extent of the difference in domestic infrastructure between the two countries. This in turn limits the extent of relocation from the poor country due to international infrastructure improvement.

4.2. *Inhibiting relocation*

Governments can and do impose rules governing plant closures that make relocation of firms either costly or impossible. (One very common way is through labor laws that make redundancies costly and difficult. In Europe, Portugal, Spain, Italy and Greece have the most restrictive policies. On the other hand, UK, Ireland and Denmark are the three most laissez-faire countries.) These rules restrict relocation of firms between regions inside a country and between countries. Is there an incentive for countries with low infrastructure to restrain capital movements and firm relocation outside of the country?

To address this question, we assume that the quality of domestic and international infrastructures are the same inside each country: $\rho_D = \rho_I = \rho$ and $\rho_D^* = \rho_I^* = \rho^*$. We also assume that $L = L^*$ and $K = K^*$. We then compare the free-trade, free-industrial-location equilibrium of Section 3 with a free-trade equilibrium in which no capital movement is allowed. In this latter equilibrium, $n = K$ and $n^* = K$. Equilibrium on the home and foreign markets for differentiated goods implies:

$$x_R = \frac{\sigma - 1}{\beta\sigma}\frac{L}{K}\left(\frac{\alpha I_R}{1+\rho^*} + \frac{\rho\alpha I_R^*}{1+\rho}\right), \tag{19a}$$

$$x_R^* = \frac{\sigma - 1}{\beta\sigma}\frac{L}{K}\left(\frac{\alpha\rho^* I_R}{1+\rho^*} + \frac{\alpha I_R^*}{1+\rho}\right), \tag{19b}$$

where the subscript R is a reminder that capital movements are restricted. Using the definitions of income in both countries, we get the following equilibrium output levels:

$$x_R = \frac{(\sigma-1)\alpha}{(\sigma-\alpha)\beta}\frac{L}{K}\frac{\sigma(1+2\rho+\rho\rho^*) - \alpha(1-\rho\rho^*)}{\sigma(1+\rho)(1+\rho^*) - \alpha(1-\rho\rho^*)}. \tag{20a}$$

$$x_R^* = \frac{(\sigma-1)\alpha}{(\sigma-\alpha)\beta}\frac{L}{K}\frac{\sigma(1+2\rho^*+\rho\rho^*) - \alpha(1-\rho\rho^*)}{\sigma(1+\rho)(1+\rho^*) - \alpha(1-\rho\rho^*)}. \tag{20b}$$

In this equilibrium, output per firm is positively related to infrastructure:

$$\frac{\partial x_R}{\partial \rho} = \frac{(\sigma-1)\alpha\sigma}{(\sigma-\alpha)\beta}\frac{L}{K}\frac{(1+\rho^*)[\sigma(1+\rho^*)-\alpha(1-\rho^*)]}{[\sigma(1+\rho)(1+\rho^*)-\alpha(1-\rho\rho^*)]^2} > 0 . \tag{21}$$

When capital cannot move, the size of firms adjusts to the higher demand for goods produced in the country with better infrastructure, and better infrastructure will induce a higher income.

In this case, will the poor infrastructure country have an incentive to restrict relocation to the good infrastructure country? There are always two contradictory effects of letting firms relocate to another country in this model. Relocation will imply a higher cost for the consumers of the country that loses firms. This is because these consumers must pay both infrastructure costs for goods produced outside the country rather than only the domestic infrastructure cost for goods produced in the country. However, income in the poor infrastructure country will rise, since capital owners can now invest in the country where infrastructure costs are lower and firms' production is larger. This implies a higher demand for these goods and therefore a higher level of profits than if firms were to stay in the poor infrastructure country. When both countries produce differentiated goods, indirect home utility with trade and unrestricted capital movements is:

$$V = \left(\frac{\sigma-1}{\beta\sigma}\right)^{\alpha}\frac{\sigma}{\sigma-\alpha}\left[K\frac{\rho(1-\rho\rho^*)}{1-\rho}\right]^{\alpha/(\sigma-1)} \tag{22}$$

where we have used the fact that $I = \sigma/(\sigma-\alpha)$.

The indirect utility function when capital movements are restricted is:

$$V_R = I_R[\rho K(1+\rho^*)]^{\frac{\alpha}{\sigma-1}} . \tag{23}$$

Using the definition of income and Eq. (20a), it can be shown that I_R depends on infrastructure in the following way:

$$I_R = \frac{\sigma}{\sigma-\alpha}\left[1+\frac{\alpha(\rho-\rho^*)}{\sigma(1+\rho)(1+\rho^*)-\alpha(1-\rho\rho^*)}\right] . \tag{24}$$

Note that income of a poor infrastructure country will be higher when capital movements are not restricted. The ratio of welfare in the poor infrastructure country with restrictions to capital movements to welfare without restriction to capital movements is, after simplification,

$$\frac{V_R}{V} = \left\{\frac{(1+\rho^*)[\sigma(1+\rho)-\alpha(1-\rho)]}{\sigma(1+\rho)(1+\rho^*)-\alpha(1-\rho\rho^*)}\right\}\left[\frac{(1+\rho^*)(1-\rho)}{1-\rho\rho^*}\right]^{\frac{\alpha}{\sigma-1}} . \tag{25}$$

If this ratio exceeds one, then welfare of the poor infrastructure country will deteriorate when firms are free to relocate. If $\rho < \rho^*$, the first bracketed

term in Eq. (25) is less than one (income rises with relocation), and the second term is greater than one (relocation induces higher infrastructure costs for consumers). It is straightforward to show that $V_R/V = 1$ when $\rho = \rho^*$, and that the partial derivative of V_R/V with respect to ρ^* is positive when evaluated at $\rho = \rho^*$. This implies that when differences in infrastructures are small between countries, the poor country will have an incentive to restrict capital outflows. In this case, the welfare loss of higher infrastructure costs is larger than the welfare gain of higher income due to relocation outside of the country. This incentive to restrict relocation will be stronger if increasing returns are strong (σ is small), if the share of differentiated goods is high (α is large) and if the overall quality of infrastructure is high.

5. Conclusions and extensions

This paper has presented a new way of modeling public infrastructure and its impact on industrial location, trade patterns and welfare. We have shown that differentials in domestic infrastructure can explain the direction of industrial relocation and that the quality of international infrastructure can explain the sensitivity of the relocation impact of differentials in domestic infrastructure or in capital endowments.

When we analyze the positive implications of our model, we treat public infrastructure as an exogenous variable. However, public infrastructure should reflect some resource constraints of the governments. A country or a region, which for historical or geographical reasons has attracted more industries, therefore has larger tax revenues, which in turn allow it to finance a better level of infrastructure. The type of circularity that generates manufacturing concentration in the models of Krugman can thus be extended to the issue of public infrastructure. This points to a double causality relation between industrial concentration and public infrastructure.

This has policy implications for regional transfers both inside and between countries (for example inside the EC). If industrial concentration has some negative effects, then public infrastructure policies can be used as an instrument to modify the geography of a country. However, as we show in our model, these policies must be biased in favor of infrastructure that facilitates domestic rather than international trade. A policy whose aim is to improve access of a poor country on the periphery to core markets and reduce or eliminate divergence in terms of international infrastructure might accelerate rather than reverse the process of industrial concentration and divergence. Our model points to some directions for an answer to whether public policies can 'reverse history' in their making of economic geography. We think that they could be more thoroughly examined.

Our paper also points to an externality which may be interesting to analyze in further research. Our model suggests that public infrastructure policies can be used as a strategic instrument to attract industries from other countries. An increase in domestic infrastructure in the home country, because of the industrial relocation it implies, increases home welfare and decreases foreign welfare. Since improving public infrastructure consumes real resources, a non-cooperative equilibrium may be characterized by a suboptimally high level of domestic infrastructure. This may have important implications for the design of infrastructure policies at the national and international level.

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