

Infrastructure and industrial location: A dual technology approach

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Abstract

The paper investigates how differences in infrastructure quality may affect industrial location between countries. Employing a dual-technology model, the main result of the paper is the somewhat surprising conclusion that an improvement in a country's infrastructure may weaken its locational advantage and induce a firm to locate production in a country with a less efficient infrastructure.

1 Introduction

This main question I wish to address in the present paper is the following: How may differences in the quality of national infrastructure affect locational choice? At first sight, the answer to this question seems obvious. Improved national infrastructure reduces transaction costs and should increase the profitability of investing in that location. Indeed, this is the result derived by Martin and Rogers (1995); firms tend to agglomerate in countries with higher quality infrastructure. They also find that the more developed is the international infrastructure that ties countries together the more responsive are firms to differences in national transaction costs.

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Using a different model framework, namely the dual-technology model that is particularly appealing for analysing less advanced economies, I derive quite different results from those of Martin and Rogers.¹ In particular, in the present model an improvement in national infrastructure in one country is likely to weaken the locational advantage of that country and make location in a country with a less efficient infrastructure more profitable. Second, an improvement in international infrastructure is likely to make it even more profitable to locate in the higher cost country. The paper is organized as follows. Section 2 presents the model and section 3 the benchmark scenario. Section 4 (to be written) contains comparative static analysis. Section 5 concludes.

2 The model

There are two regions in the model, A and B , which we shall generally refer to as countries. There are two goods, 1 and 2, produced using labor as the only input. There is no migration of workers between regions. The two goods can be produced by means of two different technologies. The "traditional" technology, which we shall also refer to as lo-tech or informal sector production, is characterized by constant returns to scale, and described by the production function

$$X_i^L = L_i^L, \quad (1)$$

where X_i^L stands for lo-tech production of good $i = 1, 2$, and L_i^L represents the labor input, superscript L indicating lo-tech. Alternatively, production may take place using "modern" technology, which we shall also refer to as hi-tech or formal sector production. Production is here characterized by increasing returns to scale, and described by

$$X_i^H = \alpha (L_i^H - F), \quad \alpha > 1 \quad (2)$$

where superscript H stands for hi-tech and α is the marginal product of labor in hi-tech production. The fixed cost F represents a capital investment and/or a licensing fee, in case the firm is not the owner of the technology.

¹I have elsewhere used the dual technology model, made popular by Murphy, Shleifer and Vishny (1989), to study issues of economic geography, see Bjorvatn (1999, 2000).

For each good there is at most one hi-tech supplier. The monopoly position of hi-tech firms can be due to patent laws, constraints in the credit market, bureaucratic barriers to entry or large fixed costs relative to market size. The hi-tech producer faces competition in its market from lo-tech production, a sector characterized by no entry barriers and perfect competition. Using wages in the lo-tech sector as numeraire, and equal to unity, given the technology in (1) we know that the supply price in this sector also equals unity.

Preferences for a representative consumer in country $J = A, B$ are given by the Cobb-Douglas utility function

$$U_J = C_{1J}^{\beta_1} C_{2J}^{\beta_2}, \quad (3)$$

where C_{iJ} is consumption of good i in country J , and β_i is the budget share of good i , where $\beta_1 + \beta_2 = 1$. With Cobb-Douglas preferences and constant marginal cost, the optimal pricing strategy of the monopolist is to match the supply price in the informal sector, thereby capturing the entire market.

The limit pricing strategy can be explained as follows. Note first that Cobb-Douglas preferences yield a unit-elastic demand curve. This implies that marginal revenue equals zero. An unconstrained monopolist would therefore raise the price without limit in order to save on production costs. The monopolist is however operating in a contestible market, facing a threat of entry from lo-tech producers, with a supply price of unity. Charging a price above unity would attract a large number of small-scale producers, making such a pricing policy unprofitable for the hi-tech producer. In other words, the threat of entry by small-scale producers defines a price ceiling for the monopolists. Charging a price below unity would not be profitable, since increased output only increases costs. Hence, the hi-tech producer always chooses a price equal to unity. The equilibrium demand for good i in country J is therefore given by

$$C_{iJ} = \beta_i Y_J, \quad (4)$$

where Y_J is aggregate disposable income in country J . Disposable income consists of labor income and (a share of the) profits generated in the country. As noted above, employment in the traditional sector yields an income of

unity. Employers in the modern sector are assumed to match this wage of unity. Hence, regular labor income in country J is L_J .

Due to for instance foreign ownership of capital, the entire value added is not necessarily spent locally. Let $\gamma_J \in (0, 1)$ define the share of value added that stays in the country, the remainder being spent in another country than the two considered here. We can think of γ_J as reflecting the bargaining strength of hi-tech labor: In addition to their regular wage of unity, the hi-tech employees receive a wage bonus in proportion to the firm's profits. An alternative interpretation is to think of γ_J as a capital income tax rate, with the remaining after tax profits leaving the country (and also leaving the model). Disposable income in country J can thus be expressed as

$$Y_J = \gamma_J \Pi_J + L_J, \quad (5)$$

where Π_J denotes value added from a firm located in country J . In case no hi-tech firm is located in the country, $\Pi_J = 0$ and hence $Y_J = L_J$.

The limit pricing strategy implies that as long as the hi-tech firm is profitable, it supplies the entire demand for its product. Hence, $C_{iJ}^H = C_{iJ}$ and $L_{iJ}^H = L_{iJ}$. The value added of a firm i locating in country J and servicing only that market is therefore given by

$$\Pi_{iJ} = C_{iJ} - L_{iJ}, \quad (6)$$

and if servicing both markets by

$$\Pi_{iJ}^* = C_{iJ} + C_{iK} - L_{iJ}, \quad J \neq K, \quad (7)$$

where the asterisk in (7) indicates that the producer is also an exporter. Transaction costs apply on both local and international sales. Since traditional production is constant returns to scale, cost minimization implies a decentralized production structure, thus avoiding transaction costs.² A hi-tech firm, on the other hand, has increasing returns to scale technology. We

²We shall also abstract from international transaction costs for the lo-tech producers. In economic terms, this assumption is reasonable if a number of these workers are located close to the border and/or if transaction costs mainly consist on various taxes that are typically not paid by the informal sector. Analytically, abstracting from transaction costs in the constant returns to scale sector ensures that the price in equilibrium is the same in both regions and equal to unity. This is a standard assumption in the literature on economic geography.

assume that it is not profitable for any firm to have more than one plant in any single country. With τ denoting per unit transaction cost, production from the modern sector firm exceeds sales by a factor $1/(1 - \tau)$, so that

$$X_i^H = \frac{C_i^H}{1 - \tau}, \quad (8)$$

where C_i^H is the consumption of good i supplied by hi-tech producer i . Note that the level of modern sector production required to satisfy any given level of demand increases exponentially with τ . Therefore, aggregate transaction costs, τX_i^H , also increase exponentially with τ . This feature of the model has some importance for the results derived later.

Profitable sales requires that the price of unity exceeds the marginal cost of supplying an extra consumption unit, which is the inverse of the marginal product of labor in hi-tech production (α) corrected for trade costs $(1 - \tau)$. Hence, profitable sales requires³

$$\pi_i > 0 \Rightarrow \tau < \frac{\alpha - 1}{\alpha}. \quad (9)$$

Let τ_J denote per unit transaction costs on sales in country J . Transaction costs on local sales are related to the quality of national infrastructure, which includes the quality of roads, railroads and telecommunication, bureaucratic efficiency, etc. Let $\tau_J^* \equiv \tau^* + \tau_J$ denote per unit transaction costs on sales from another market to country J . In addition to the costs related to the distribution of the goods in J , these costs include costs related to the quality of international infrastructure. Denoted by τ^* , these costs are determined by the quality of international harbors and airports, and the administrative capacity and efficiency in trade-administration in the country of origin and the country of destination.⁴

Note that with the formulation above, transaction costs associated with exports to J are unaffected by the quality of national infrastructure in K .

³Using (2) and (8), profits can be expressed as $\Pi_i = C_i^H - L_i^H = X_i^H(1 - \tau) - (X_i^H/\alpha + F)$, and operating profits as $\pi_i = X_i^H(1 - \tau) - X_i^H/\alpha$. The condition $\pi_i > 0$ results in (9).

⁴The reader should note an asymmetry between the present model and the one by Martin and Rogers in the treatment of transaction costs. In the present paper, per unit transaction costs on exports are always lower when selling to the country with the lower national transaction costs. In the paper by Martin and Rogers, the quality of national infrastructure is irrelevant in case of exports. In their formulation, then, per unit sales costs on exports are therefore the same in both locations.

One might argue that this is not very realistic. If, for instance, the large scale producer is located at some distance from the port or the border, the quality of the local road system would affect the profitability of exports. However, as will become clear in an extension to the model, the qualitative results do not hinge on this particular assumption. Since it is instructive to treat national and international infrastructure separately, we choose this formulation in the basic version of the model. Using (2), (4), and (5), (6) can be expressed as⁵

$$\Pi_{iJ} = \mu_J \left[\beta_i L_J \left(1 - \frac{1}{\alpha(1 - \tau_J)} \right) - F \right], \quad (10)$$

and (7) as

$$\begin{aligned} \Pi_{iJ}^* = & \mu_J \left[\beta_i L_J \left(1 - \frac{1}{\alpha(1 - \tau_J)} \right) \right] + \\ & \mu_J \left[\beta_i L_K \left(1 - \frac{1}{\alpha(1 - (\tau^* + \tau_K))} \right) - F \right], \end{aligned} \quad (11)$$

where

$$\mu_J \equiv \frac{\alpha(1 - \tau_J)}{\alpha(1 - \tau_J)(1 - \gamma_J \beta_i) + \gamma_J \beta_i} \quad (12)$$

is the multiplier, linking income with demand and thereby value added for a firm located in country J .

3 Analysis

We wish to study how a reduction in transaction costs in the present framework affects locational choice. Assume that initially the two countries are identical and that transaction costs are such that the effective market size is too small to permit profitable large scale production. This can be thought of as the pre-industrialization phase. We then let transaction costs in one country (country A) go down, holding transaction costs in the other (country B) constant. We consider entry of only one firm. This allows us to focus on the way in which transaction costs affects profits and hence locational

⁵See the Appendix A for the derivation.

choice in large scale production. Allowing for entry of additional firms would introduce such issues as agglomeration effects and multiple equilibria to the model. Such effects are well understood from the literature on economic geography, and will not be discussed here.

While it is possible to discuss locational choice using the general expression (10) and (11), such an analysis would involve extremely complicated formulae that do not lend themselves easily to economic analysis. Instead, we shall proceed by use of numerical examples. Let the benchmark scenario be defined by the data in Table 1 below.

Table 1. Benchmark data

L_A	L_B	γ_A	γ_B	α	β_i	τ_B	F
1	1	0.25	0.25	2	0.5	0.35	0.15

With $F = 0.15$ we see from (10) that positive profits in autarky is contingent on $\tau_J < 0.35$. Hence, given the initial situation of $\tau_A = \tau_B = 0.35$, a large scale producer will only enter if there it can also make profits from exports. Note that with $\alpha = 2$, and given the initial level of national transaction costs, from (9) we know that profitable exports requires $\tau^* < 0.15$.

Figure 1 illustrates the benchmark case. The vertical axis measures international transaction costs and the horizontal axis measures country A transaction costs. Region I is the area in which exports are profitable from both countries, which is true for $\tau^* < 0.15$. Region II is the area where only exports from B to A are profitable, i.e., where $\tau^* > 0.15$ and $\tau^* + \tau_A < 0.5$. In region III , exports are not profitable from either region, i.e., $\tau^* + \tau_A > 0.5$. On the PI -line, locating in A and B yields the same profits, given that exports are profitable from both regions, i.e., given that we are in area I .⁶ Below PI , country A is the more profitable location, and above it, locating in country B is more profitable. On the PII -line, the firm is indifferent between locating in A and B , given that exports are only profitable from B to A , i.e., given that we are in region II . In region III there is autarky, in which case it is always more profitable to locate in the region with the better local infrastructure, which here means country A . The shaded area in Figure 1 shows the combinations of τ^* and τ_A for which locating in the higher cost country B is more profitable.

Initially, we are at point a with two symmetric regions characterized by $\tau_A = \tau_B = 0.35$. Moreover, since $\tau^* > 0.15$, trade, and hence hi-tech entry, is

⁶See Appendix B for the derivation of the PI and PII -lines.

not profitable. Let us first consider how a reduction in τ_A affects locational choice, holding τ^* constant. Lowering national transaction costs in A and moving to point b makes hi-tech production profitable in A . Since we are in region III , exports is not profitable in either direction. Hence, at point b , locating in B would result in negative profits for the firm. Moving to c brings us to region II . Locating in B would now be feasible, since exports to A is profitable. Since we are to the right of the PII line, however, it is more profitable to locate in A . Clearly, at this point, export earnings are not enough to compensate for the disadvantage of being located in the high-cost country B . Moving to d brings us to the left of the PII line. At this point, export earnings more than outweigh the disadvantage of being located in the high-cost country. The firm therefore chooses to locate in B . This result can be summarized as:

Proposition 1 *A reduction in national transaction costs in the country with the better infrastructure may induce a firm to locate in the higher cost country.*

Intuitively, improving the national infrastructure in A not only increases the profits of local production but also increases profitability of accessing that market from abroad. The advantage of locating in the higher cost country B is lower cost access to the local customers. In fact, in region II , the only way of profitably servicing consumers in B is to locate production there. When the transaction costs associated with exporting to A are reduced sufficiently, locating in B is the more profitable choice.

Let us now consider the effect on location of a reduction in international transaction costs, keeping τ_A constant. Starting in c , a reduction in τ^* bringing us to e also leads to a relocation from A to B . The reason is basically as we described when considering the move from c to d ; the reduced international transaction costs increases the accessibility of market A and thus increases the profitability of locating in B . Moving from e to f brings us to region I , in which exports are profitable in both directions. Since consumers in B may now be served also from A , one might perhaps think that this would automatically induce location in A . However, as discussed earlier, total transaction costs increase exponentially with per unit transaction costs. Locating in A would add τ^* to the already high local transaction costs of servicing market B , leading to a large increase in total transaction costs. Keeping transaction costs at a minimum therefore implies locating in B . Moving to g we cross the PI -line, and here locating in A is the more profitable

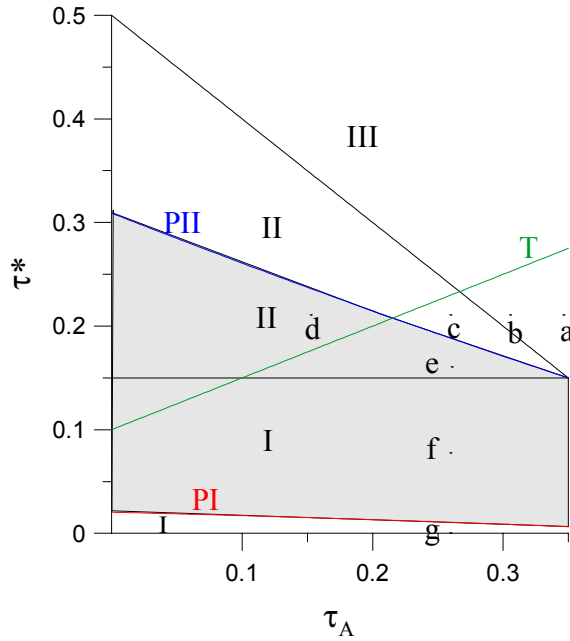


Figure 1: Equilibrium location

choice. The reason is that moving from B to A adds very little, and in the extreme case of $\tau^* = 0$, nothing, to total transaction costs. It is then more profitable to locate in the lower cost country. This discussion can be summarized as:

Proposition 2 *Starting from a high (low) level of international transaction costs, a reduction in these costs may induce a firm to locate in the higher (lower) cost country.*

4 Comparative statics

An increase in L_i obviously increases the profitability of locating in that region. A symmetric increase in labor supply in the two regions makes location in country A more likely. In Figure 1, the PI -line would shift upwards and the PII -line downwards. Intuitively, the larger are the markets, the more important it is to be located in the market with the lower transaction costs.

An increase in α makes large scale production more profitable. Exports are now profitable for a larger range of transaction costs, implying an upward shift in the line separating region *II* and *III*, and, similarly, an upward shift in the line separating region *I* and *II*. It can be shown that an increase in α shifts both the *PI* and the *PII*-line upwards. This implies that locating in region *B* becomes more likely when international transaction costs are relatively high, and that *A* becomes the more likely location when international transaction costs are low. Intuitively, an increase in α increases the markup on each unit sold, thus making access to a larger market more important. When international transaction costs are high, we know that locating in *B* is the only way to service both markets (region *II*). An increase in α increases the importance of this strategy. When τ^* is low, however, exports are possible from both locations (region *I*). Since higher α means higher profits and therefore larger sales, the importance of locating in the market with the lower transaction costs increases.

A lower F , by shifting the *PI*-line upwards and the *PII*-line downwards, increases the likelihood that *A* will be the preferred location. The reason is basically that, as above, lower F means higher profits and therefore larger sales, which in turn increases the importance of locating in the market with the lower transaction costs.

5 Extension: On transaction costs

One might argue that the separation between national and international transaction costs is artificial. Improving the quality of national infrastructure in a country is likely to improve also the quality of international infrastructure, thus making exports from this country more profitable. Since the quality of national infrastructure in *B* is taken as given, international transaction costs in this country (τ^{B*}) are also held constant, and given by ξ . Let international transaction costs in *A* be described by $\tau^{A*} = \theta\tau_A$, where θ captures the degree to which a change in τ_A affects the costs of exporting from that country. International transaction costs can then be described by

$$\tau^* = \tau^{A*} + \tau^{B*} = \xi + \theta\tau_A. \quad (13)$$

Thus extending the benchmark scenario, it is straightforward to demonstrate that as long as $\xi < 0.31$, i.e., the point where the *PII*-line intersects the vertical axis, Proposition 1 holds for any $\theta > 0$. Figure 1 illustrates the

case of $\xi = 0.1$ and $\theta = 0.5$, given by the T -line. In this specific example, a reduction in τ_A leads to an equal reduction in τ^* . Clearly, a reduction in τ_A bringing us from a point on the T -line above the PII -line to a point on the T -line below this line, would induce a change of location for the hi-tech firm from A to B . Hence, as long as the relatively poor infrastructure in B does not affect its exporting potential too much, i.e., as long as $\xi < 0.31$, improving country A 's infrastructure will eventually lead to a relocation of production to the higher cost country, exactly as in the benchmark case.

6 Conclusion

The effect of economic integration is a highly debated issue in both political and academic circles. The most important question is perhaps whether closer economic integration will promote balanced development or increased inequalities between countries. Inspired by Martin and Rogers (1995), but using a dual-technology model made popular by Murphy, Shleifer and Vishny (1991), the article focuses on transaction costs on two levels; national and international.

The main result is that a reduction in national transaction costs in the country with the more efficient national infrastructure may induce a firm to locate in a country with lower-quality infrastructure. This result should be interpreted as saying that improved infrastructure in a more developed country may increase the location advantage of neighbouring less developed countries. Relative to the result derived by Martin and Rogers, this is good news for countries with less developed infrastructure. Note that the result should not be interpreted as saying that improved infrastructure will automatically lead to firms leaving that country. Agglomeration effects may reduce the likelihood of firms moving out of established industrial clusters once they are established.

Reducing international transaction costs may or may not induce location in the higher cost region. Starting from a high level of international transaction costs, a reduction in these costs is likely to lead to location in the country with the poorer national infrastructure. Starting from a lower level of international transaction costs, a reduction in these costs may make the country with the better national infrastructure the more attractive location.

Appendix A

Reformulating (2), we find that

$$L_1^H = \frac{X_1^H}{\alpha} + F. \quad (\text{A1})$$

In the autarky case, a firm located in J only serves that market, so that $C_i^H = C_{iJ}$. Using this information together with (8), (A1) can be written as

$$L_i^H = \frac{C_{iJ}}{\alpha(1-\tau_J)} + F. \quad (\text{A2})$$

Insert this expression into (6), and we get

$$\Pi_{iJ} = C_{iJ} \left(1 - \frac{1}{\alpha(1-\tau_J)} \right) - F. \quad (\text{A3})$$

Using (4) and (5), we can express this as

$$\Pi_{iJ} = \beta_i (\gamma_J \Pi_{iJ} + L_J) \left(1 - \frac{1}{\alpha(1-\tau_J)} \right) - F, \quad (\text{A4})$$

which solving for Π_{iJ} results in (10). To arrive at (11), note that $C_i^H = C_{iJ} + C_{iK}$, so that (A1) can be written as

$$L_i^H = \frac{C_{iJ}}{\alpha(1-\tau_J)} + \frac{C_{iK}}{\alpha(1-(\tau^* + \tau_K))} + F. \quad (\text{A5})$$

Then, using the same procedure as above, we can easily derive (11).

Appendix B

The *PII*-line

Region II

$$\begin{aligned} \Pi_A &= \frac{2(1-\tau_A)}{2(1-\tau_A)(1-\frac{1}{4}(\frac{1}{2})) + \frac{1}{4}(\frac{1}{2})} \left(\frac{1}{2} \left(1 - \frac{1}{2(1-\tau_A)} \right) - \frac{3}{20} \right) \\ \Pi_B^* &= \frac{2(1-\frac{7}{20})}{2(1-\frac{7}{20})(1-\frac{1}{4}(\frac{1}{2})) + \frac{1}{4}(\frac{1}{2})} \left(\frac{1}{2} \left(1 - \frac{1}{2(1-\frac{7}{20})} \right) + \frac{1}{2} \left(1 - \frac{1}{2(1-(\tau^* + \tau_A))} \right) - \frac{3}{20} \right) \\ \Pi_A &= \Pi_B^* \Rightarrow \\ \tau^* &= -\frac{436-781\tau_A+280\tau_A^2}{-1411+280\tau_A}, \end{aligned}$$

which defines the *PII*-line

The *PI*-line

Region I

$$\Pi_A^* = \frac{2(1-\tau_A)}{2(1-\tau_A)\left(1-\frac{1}{4}\left(\frac{1}{2}\right)\right)+\frac{1}{4}\left(\frac{1}{2}\right)} \left(\frac{1}{2} \left(1 - \frac{1}{2(1-\tau_A)} \right) + \frac{1}{2} \left(1 - \frac{1}{2(1-(\tau+\frac{7}{20}))} \right) - \frac{3}{20} \right)$$

Π_B^* as for Region *II* above

$$\Pi_A^* = \Pi_B^* \Rightarrow$$

$$\tau^* = -\frac{1}{2}\tau_A + \frac{2771}{3480} - \frac{1}{3480} \sqrt{(3027\ 600\tau_A^2 - 8800\ 920\tau_A + 7288\ 681)},$$

which defines the *PI*-line

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