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Asymmetric inter-regional transportation costs, industrial location and growth

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Abstract

This paper incorporates asymmetric inter-regional transportation costs into the two-region endogenous growth model in Martin and Ottaviano (1999) to investigate the growth effects of an increase in the cost of transporting goods from the Sough (North) to the North (South). We show that with local research and development spillovers, an increase in the transportation cost to the North (South) increases (decreases) the world growth rate through an increase (decrease) in the concentration of firms in the North.

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1. Introduction

This paper provides a framework that is useful for understanding the role of asymmetric inter-regional transportation costs in determining industrial location and the growth rate given local spillovers in innovative research and development (R&D).

The economic literature dealing with geographic space and economic growth is now quite voluminous. See, for example, Martin (1999), Baldwin (1999), Martin and Ottaviano (1999, 2001), Baldwin and Forslid (2000), and Baldwin, Martin, and Ottaviano (2001). For instance, Martin and Ottaviano (1999) combine the endogenous growth model in Grossman and Helpman (1991) and the location model in Martin and Rogers (1995) to account for the impact of openness on the world growth rate through the effect on industrial location. However, the models proposed in the literature lack a proper adjustment mechanism for the relationship between the geographic space in which a firm operates and asymmetric inter-regional transportation costs. This is because all of these models assume symmetric transportation costs. One possible exception is Martin (1999), who studies how the asymmetry of transportation costs affects the world growth rate by employing a two-region endogenous growth model. However, his study focuses on the asymmetry of intra-regional transportation costs to examine the growth effect.[1] The other possible exception is Leite, Castro and Correia-da-Silva (2009), who extend the static model of Krugman (1991) to incorporate asymmetric inter-regional transportation costs and study how the asymmetry of inter-regional transportation costs affects the industrial activities in a region by numerical simulations.[2]

However, the following question remains unresolved: how does the relationship between the world growth rate and the spatial distribution of firms change when we take into account asymmetric inter-regional transportation costs? Furthermore, how does the asymmetry of inter-regional transportation costs affect industrial location and growth? To study the effect of an increase in the asymmetry of inter-regional transportation cost on the world growth rate through the effect on industrial location, we apply the two-region endogenous growth model in Martin and Ottaviano (1999). This particular analysis demonstrates that with local spillovers in R&D, an increase in the cost of transporting goods from the South to the North increases the world growth rate through the greater concentration of firms in the North (whereas an increase in the cost of transporting goods from the North to the South lowers the growth rate through the lower concentration of firms in the North)

The remainder of the paper is structured as follows. Section 2 outlines the features of the model. Section 3 describes the equilibrium location and firm size and Section 4 details the R&D sector. In Section 5, we examine the impact of an increase in the cost of transporting goods from the South (North) to the North (South) on the world growth rate through industrial location. The final section concludes the paper.

[1] For related works, Martin and Rogers (1995) and Takahashi (2007) generalize the static model of Krugman (1991) to incorporate asymmetric intra-regional transportation costs and study how the asymmetry of intra-regional transportation costs affects the equilibrium share of firms.

[2] Kikuchi (2008) also studies how the asymmetry of inter-regional transportation costs affects the industrial activities in a region by employing the static model of Martin and Rogers (1995).

2. Model structure

We assume a two-region economy comprising North and South locations. The models for the North and South are identical save their initial stock of capital and transportation costs. We use an asterisk to denote the variables for the South. Henceforth, we mainly focus on a description of the Northern economy given the equivalence with the Southern economy. Unlike owners (households/workers), firms in this model are internationally mobile.

Both North and South households have perfect foresight and share the same utility function. The intertemporal objective of a representative household in the North is to maximize the following lifetime utility:[3]

$$U = \int_0^{\infty} \log\left[D(t)^{\alpha} Y(t)^{1-\alpha}\right] e^{-\rho t} dt, \tag{1}$$

where ρ is the subjective discount rate, which is also identical in both countries, $Y(t)$ is the numeraire good in period t, and the consumption index $D(t)$ is defined as follows:

$$D(t) = \left[\int_{i=0}^{N(t)} D_i(t)^{1-1/\sigma}\right]^{1/(1-1/\sigma)}, \ \sigma > 1, \tag{2}$$

where σ is the elasticity of substitution between any two differentiated goods, $D_i(t)$ is the consumption of good i in period t, and $N(t)$ is the total number of differentiated goods produced in both the North and the South. In this model, we introduce transportation costs on the differentiated goods. However, there is no transportation cost on the numeraire good. Here, we assume asymmetric iceberg transport costs in shipping the differentiated goods between countries. Specifically, τ_N ($\tau_N \geq 1$) units of a differentiated good have to be shipped from the South to the North for one unit to arrive at its destination. Similarly, τ_S ($\tau_S \geq 1$) units of a differentiated good have to be shipped from the North to the South for one unit to arrive at its destination. The per capita expenditure of a typical North household E is then:

$$\int_0^n p_i D_i di + \int_0^{n^*} \tau_N p_j^* D_j dj + Y = E, \tag{3}$$

Henceforth, we omit the time subscript. In this model, as shown in (3), the North consists of n firms and the remaining n^* firms are in the South, where n and n^* are endogenous and $n + n^* = N$ holds at each point in time. p_i is the producer price of a typical variety i in the North and p_j^* is its price in the South. The consumption price indices for the differentiated products are then:

$$P = \left(\int_0^n p_i^{\ 1-\sigma} di + \int_0^{n^*} \left(\tau_N p_j^*\right)^{1-\sigma} dj\right)^{1/(1-\sigma)}, \tag{4}$$

$$P^* = \left(\int_0^n \left(\tau_S p_i\right)^{1-\sigma} di + \int_0^{n^*} p_j^{*\ 1-\sigma} dj\right)^{1/(1-\sigma)}, \tag{5}$$

[3] This specification of the intertemporal preferences allows a steady-state solution in which expenditures are constant across periods, even though utility grows over time.

where P (P^*) is the price index in the North (South). In the differentiated goods sector, a patent is required to begin producing each variety of good, and therefore we can interpret this capital requirement as a fixed production cost. This immaterial capital requirement, however, allows a given patent owner to produce in more than one location at once, in principle. In order to exclude the case where the patent can be used in more than one location at once, as in Martin (1999), we need to interpret the patent as a fixed cost inclusive of a piece of machinery (or one unit of physical capital). However, in this paper, as in Martin and Ottaviano (1999), we also assume that a given patent owner produces a single differentiated good in only one location (a one-to-one correspondence between varieties and locations). Each firm issues equities to finance the fixed cost of the patent and distributes all profits to shareholders as dividends. In addition, each good requires β units of labor. Standard profit optimization by the choice of p_i yields $p_i = w\beta\sigma/(\sigma - 1)$. The profit flow of each firm in the differentiated goods sector is then:

$$\pi_{IRS} = p_i x_i(p_i) - w\beta x_i(p_i) = \frac{w\beta x}{(\sigma-1)}, \tag{6}$$

where x is the size of output.

The homogeneous good Y is assumed to be produced using some constant returns to scale technology that requires labor as the only input where firms devote one unit of labor to produce one unit of Y. In addition, we assume that some production of the homogeneous good is active in both locations. Hence, we ensure factor-price equalization across locations $w = w^*$ at each instant because of free trade in the homogeneous good. As the numeraire is the homogeneous good, the wage rate in each location is $w = w^* = 1$. Therefore, we obtain $p = p^* = \beta\sigma/(\sigma - 1)$.

Here, we define $\delta_N \equiv \tau_N^{1-\theta} \in (0, 1)$ and $\delta_S \equiv \tau_S^{1-\theta} \in (0, 1)$ for convenience. From standard utility optimization given the choices of D_i, D_j and Y, each household spends a constant fraction α of its consumption expenditure E on the differentiated goods and the remaining $(1 - \alpha)$ of E on good Y:

$$D_i = \frac{\sigma-1}{\beta\sigma}\frac{\alpha E}{n+n^*\delta_N}, \tag{7a}$$

$$D_j = \frac{\sigma-1}{\beta\sigma}\frac{\tau_N^{-\sigma}\alpha E}{n+n^*\delta_N}, \tag{7b}$$

$$Y = (1-\alpha)E. \tag{7c}$$

Next, we consider the stock market valuation of profit-making firms. Here, we define v as the equity value of a firm and r as the return on a riskless bond. A no-arbitrage condition in capital markets relates the expected return on equity to the return on an equally sized investment in the riskless bond. Therefore, by considering (6), we obtain:

$$\frac{\beta x}{\sigma-1}+\dot{v}=rv\,. \tag{8}$$

Next, we solve the intertemporal optimization problem. The maximization of (1) subject to the intertemporal budget constraint and free capital mobility between locations requires that nominal expenditures grow at an instantaneous rate equal to r – ρ:

$$\frac{\dot{E}}{E}=\frac{\dot{E}^*}{E^*}=r-\rho\,. \tag{9}$$

As a result, if a balanced growth path exists, then nominal expenditures must be constant and, consequently, $r = \rho$.

3. Firm sizes and locations

Here, we determine firm sizes (x, x^*) and locations (n, n^*) for a given level of expenditure (E, E^*). Aggregating the demands in (7a) and (7b) across all households worldwide yields the following market-clearing condition for any differentiated product x:

$$x=\frac{\alpha L(\sigma-1)}{\beta\sigma}\left(\frac{E}{n+n^*\delta_N}+\frac{\delta_S E^*}{n^*+n\delta_S}\right), \tag{10a}$$

where L is the amount of labor endowment that is equal in both locations. Similarly, for any product x^*, we obtain:

$$x^*=\frac{\alpha L(\sigma-1)}{\beta\sigma}\left(\frac{\delta_N E}{n+n^*\delta_N}+\frac{E^*}{n^*+n\delta_S}\right). \tag{10b}$$

The model assumes that firms do not face any relocation costs so relocating does not require any time. For a firm to be indifferent between the North and the South locations following location arbitrage, the operating profits from the two locations must also be equal:

$$\pi_{IRS}=\pi^*_{IRS}\,. \tag{10c}$$

Therefore, from equation (6), (10c) and $w = w^* = 1$, we obtain $x = x^*$. Here, we set K and K^* as the number of firms owned by the North and the South, respectively. In addition, the total stock of capital owned by agents fixes the total number of firms, such that:

$$n+n^*=K+K^*=N\,. \tag{10d}$$

Solving (10a)–(10d), we obtain the share of firms in the North, where we define γ as:

$$\gamma = \frac{n}{N} = \frac{(1-\delta_N)E - (1-\delta_S)\delta_N E^*}{(1-\delta_N)(1-\delta_S)(E+E^*)} = \frac{(1-\delta_N)(1-\delta_S)E^* + (1-\delta_N)E - (1-\delta_S)E^*}{(1-\delta_N)(1-\delta_S)(E+E^*)}. \quad (11)$$

The level of output of each firm is:

$$x = \alpha L \frac{\sigma - 1}{\beta\sigma} \frac{E + E^*}{N}. \quad (12)$$

This is identical to that in Martin (1999) and Martin and Ottaviano (1999).

4. R&D sector with local spillovers

Next, we turn to the R&D sector. We assume that forward-looking researchers decide on the amount of R&D investment, and that the R&D technology is linear, whereby the invention of a new good is directly proportional to the labor devoted to the activity. To consider the incentive for researchers to engage in innovative R&D, let v denote the value of a blueprint developed through innovative R&D. Following Martin and Ottaviano (1999), we assume that the cost of R&D in a location is negatively proportional to the number of firms already located in that location, in which a researcher that undertakes R&D activities employs η/n units of labor in the North and η/n^* in the South. This implies that if the number of firms producing in the North differs from that in the South, all R&D activity takes place in the location with the larger number of firms.

Here, Martin (1999) and Martin and Ottaviano (1999) assume $K_0 > K_0^*$ as an initial condition such that the preexisting stock of patents is initially larger in the North than the South. This condition determines which location has the larger market size (or the larger level of expenditure). Indeed, under this condition, the level of expenditure in the North is larger than the South through the differential in capital incomes. In addition, in their model, the number of firms in the North is predicated on the differential in expenditures (and hence the relative size of market in each location). As a result, in their model where the R&D cost in a location is negatively proportional to the number of firms in that location, all R&D activity takes place in the North.

On the other hand, in our model with asymmetric inter-regional transportation cost, the corresponding initial condition is rewritten as $(1 - \delta_N)K_0 > (1 - \delta_S)K_0^*$. Under the condition of $(1 - \delta_N)K_0 > (1 - \delta_S)K_0^*$, the North with its larger transportation cost ends up with the larger market size. Consequently, all R&D activity takes place in the North and this entirely determines the world growth rate. Free entry into the R&D sector, therefore, leads to $v = \eta/n$.

5. Asymmetric transportation costs, location and growth

In this section, we derive the solution for a steady state in which the share of firms in the North and the growth rate of N do not change (i.e., $\gamma = n/N$ and g $(= \dot{N}/N)$ are constants).[4] As the equity value of each firm equals that of the blueprint it owns, the equity value of any firm v is determined by the free-entry condition in the R&D sector:

[4] Note that the steady state results depend on very restrictive assumptions about intertemporal preferences where across period preferences are logarithmic.

$v = \eta/N\gamma$. If a balanced growth path exists, this implies that v decreases at rate $g = \dot{N}/N = \dot{n}/n$. The world labor market-clearing condition is the same as that in Martin and Ottaviano (1999):

$$\eta\frac{g}{\gamma}+\left(\frac{\sigma-\alpha}{\sigma}\right)L\left(E+E^{*}\right)=2L\,. \tag{13}$$

If both g and γ are constant in the steady state, then equation (13) implies that expenditures must be constant. This leads to $r = \rho$. Then, substituting equation (12), $v = \eta/N\gamma$, and $r = \rho$ into equation (8) yields the following equilibrium growth rate:

$$g=\frac{2L}{\eta}\frac{\alpha}{\sigma}\gamma-\left(\frac{\sigma-\alpha}{\sigma}\right)\rho\,. \tag{14}$$

Equation (14) shows that the greater the share of firms in the North (= γ), the higher the world growth rate (= g).

Then, the respective steady-state levels of per capita expenditure for each location are:

$$E=1+\frac{\rho\eta k}{\gamma L},\; E^{*}=1+\frac{\rho\eta(1-k)}{\gamma L} \tag{15}$$

where $k = K/N$. Substituting (15) into the equilibrium share of firms in the North given by equation (11) yields the following quadratic equation in γ:

$$2L\gamma^{2}+\left\{\rho\eta-\left[\frac{1-\delta_{N}-(1-\delta_{S})\delta_{N}}{(1-\delta_{N})(1-\delta_{S})}\right]L\right\}\gamma-\rho\eta\left[\frac{k}{1-\delta_{S}}-\frac{\delta_{N}(1-k)}{1-\delta_{N}}\right]=0\,. \tag{16}$$

The positive root to this equation,

$$\gamma=\frac{-\left\{\rho\eta-\left[\frac{1-\delta_{N}-(1-\delta_{S})\delta_{N}}{(1-\delta_{N})(1-\delta_{S})}\right]L\right\}}{4L}+\frac{\sqrt{\left\{\rho\eta-\left[\frac{1-\delta_{N}-(1-\delta_{S})\delta_{N}}{(1-\delta_{N})(1-\delta_{S})}\right]L\right\}^{2}+8L\rho\eta\left[\frac{k}{1-\delta_{S}}-\frac{\delta_{N}(1-k)}{1-\delta_{N}}\right]}}{4L}, \tag{17}$$

is the valid solution. From (17), we obtain the parametric condition required for γ to lie between 1/2 and 1 ($1 > \gamma > 1/2$):

$$\frac{(1-\delta_N)(1-\delta_S)}{2}+\frac{L(\delta_N-\delta_S)}{2\rho\eta}<(1-\delta_N)k-\delta_N(1-\delta_S)(1-k)$$
$$<(1-\delta_N)(1-\delta_S)+\frac{L[1-\delta_s-\delta_s(1-\delta_N)]}{\rho\eta}. \tag{18}$$

Note that when there is a corner solution with all differentiated goods produced in the North ($\gamma = 1$), the growth rate is independent of the share of firms in the North location (see equation (14)). In what follows, we assume that (18) is valid, so that both countries produce the differentiated products.

Next, we analyze the effects of an increase in the cost of transporting goods from the South (North) to the North (South) on the world growth rate through the effect on industrial location. From equation (17), we obtain:

$$\frac{\partial\gamma}{\partial\delta_N}<0,\ \ \frac{\partial\gamma}{\partial\delta_S}>0. \tag{19}$$

Recall our earlier explanation of the world growth rate depending positively on the share of firms in the North location given equation (14). Therefore, equation (19) implies that an increase in the cost of transporting goods from the South to the North will increase the world growth rate through the greater concentration of firms in the North (whereas an increase in the cost of transporting goods from the North to the South will lower the growth rate through the lower concentration of firms in the North).[5]

6. Conclusion

This paper analyzed the effect of an increase in the cost of transporting goods from the South (North) to the North (South) on the world growth rate through the effect on industrial location. The results indicate that with local spillovers in innovative R&D, an increase in the cost of transporting goods from the South (North) to the North (South) will raise (lower) the world growth rate through the greater (lower) concentration of firms in the North location.

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[5] We thank a referee for this interpretation.

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