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Coordination cost and the distance puzzle

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(june 2010 - Preliminary version)

Abstract

Since 1960, transport costs has been falling, but international exchange became more sensitive to distance. We solve this distance puzzle in the following way: decrease in transport cost favors trade, which increases the international specialization. An increased international specialization increases the need for coordination, and makes it relatively more important for downstream firms to be close to their suppliers.

Key words:

Transport cost, coordination cost, international trade, distance puzzle

JEL Classification: F12, F15

Introduction

The distance puzzle has been wildly discussed in the literature since Leamer and Levinsohn (1995) shed the light on it. This puzzle simply says that “the world is not getting smaller”: distance still matters to account for trade. This is reflected in a decreasing distance of trade (DOT) as pointed out by Carrère and Schiff (2005), or, according to the meta analysis performed by Disdier

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and Head (2008), in a stable or increasing (negative) elasticity of trade with respect to distance.

Several explanations of this puzzle have been emphasized. Coe et al. (2002) point out four of them. The first one is relative to the differentiated effects of a fall in average transport costs and a fall in marginal transport costs. Thus, the distance puzzle could be explained by a deeper fall in average cost than in marginal one. The second explanation relies on the dispersion of economic activities (Leamer and Levinsohn (1995)) and more broadly on the uneven growth of countries (Carrère and Schiff (2005), Coughlin (2004)). The intuition behind can be summarized as follows: the dispersion of economic activities that have occurred with the development of countries such as China, India, Mexico explains the dramatic increase of trade. However Coe et al. (2002) reject it for two reasons: i) a look at firms location indicates a greater concentration of economic activities and not a greater dispersion; ii) the economic mass is included in gravity equation and controlled for it. In this vein, Carrère and Schiff (2005) and Coughlin (2004) argue that when neighbors countries are developing, this increases trade between them. More precisely, Carrère and Schiff (2005) showed that distance of trade (DOT) within countries of South-East Asia have sharply decreased and in the meantime, several countries within the neighborhood have been developing. The third explanation is related to a compositional effect, ie. the sensitivity of distance would have decreased for each type of good, but the share of goods that are more sensitive to distance would have increased. Disdier and Head (2008) mention this effect as a possible explanation of the distance puzzle. However, Berthelon and Freund (2008) did not confirm empirically this effect. Indeed they showed that the increase in the average coefficient of distance in gravity equations between 1985-89 and 2001-04 is due to the increase in the coefficient of distance for 40% sectors⁴. The fourth explanation highlighted by Coe et al. (2002) focuses on the relative trade costs vs absolute trade costs. Indeed, if transport costs with neighbors countries fall deeper than transport costs with distant countries, trade with neighbors would be higher than with distant ones. However, Coe et al. (2002) reject this explanation because empirical evidence suggests that transport costs with distant countries have fall more than transport costs with neighbors ones. This result makes the falling trend of DOT (Carrère and Schiff (2005)) even more puzzling.

There are two others explanations of the distance puzzle in the international economics literature. The first one is related to the creation of trade agreements. Indeed, trade agreements enhance trade between countries that are geographically close (since those agreements are usually concluded between neighbors), then it could lower DOT of countries without reflecting an in-

⁴ They linked this increased coefficient with the level of substitutability of goods, i.e. homogenous goods are more sensitive to the distance than differentiated ones.

creasing sensitivity of goods to distance. This effect was studied by Carrère and Schiff (2005) for eight free trade area during 1962-2000. They found an average effect of Regional Integration Agreements (RIAs) on the trend of DOT equal to -0.20% . However, they also highlighted that the share of countries with an increasing trend of DOT is twice larger inside those trade blocs than outside. On the other hand, when Coughlin (2004) have studied the impact of NAFTA on Amercian trade flows, he noted that since the creation of NAFTA, while amercian exports with NAFTA members (ie Canada and Mexico) have increased, the same applied with Asian countries, whereas exports with non-member Latin-American countries have decrease despited their geographical proximity. They suggest that these changes in Amercian exports are not only due to NAFTA's creation but also to economic growth. Indeed, during this period Canada, Mexico and Asia were among the highest growth rate in the world whereas Latin America did not (Coughlin (2004)).

Finally, Brun et al. (2005) and Duranton and Storper (2008) argued that the fall in transport cost can be compatible with the increase in distance sensitivity because transport costs are only one component of trade costs. Then, if other components of trade costs increase, a fall in transport costs is not enough to lower trade costs. In Brun et al. (2005) trade costs encompassed the real price of oil, the level of infrastructure and the real exchange rate.

To our knowledge, only Duranton and Storper (2008) have proposed a full theoretical framework to account for this puzzle. Their argument can be summarized as follows: a lower transport cost allows firms to trade higher quality goods. But those goods are more expansive to trade, since the transfer cost of good is an increasing function of their quality. Formally, let ζ be the share of the quality Q of a machine that is lost in transport. Assume this quality is measured in terms of labour used in the production of the machine. If the willingness to pay for one machine is $Q^{1-\psi}$ ($\psi \in]0; 1[$), it is easy to check that the profit-maximizing quality is $\left[\frac{(1-\zeta)^{1-\psi}(1-\psi)}{\omega} \right]^{1/\psi}$, where ω is the wage rate. This expression is decreasing in ζ . Now, the transfer cost is just the amount of that quality that is lost in transport, ie $\zeta \left[\frac{(1-\zeta)^{1-\psi}(1-\psi)}{\omega} \right]^{1/\psi}$, which is a reverted-U shaped function of ζ . In this model, the distance puzzle would only apply for high transport costs. So, the long-run prediction of this model is that this puzzle will disappear if $\zeta \rightarrow 0$.

Our paper proposes a new theoretical explanation of this puzzle. This explanation shares with Duranton and Storper's two important characteristics: i) there is a non monotonic relationship between transport cost and trade cost. ii) this phenomenon is due to contract incompleteness. However, the mechanism that we underline is quite different: in our model, based on a Dixit-Stiglitz increasing return to scale technology, a fall in transport cost increases the international division of labour. It follows that input-output linkages require

a higher level of coordination. Such a coordination is easier between neighbors than between very distant countries. As a result, trade increases with all partners, but more quickly for neighbors than for distant countries. The main difference with Duranton & Storper is the shape of the relationship between transport cost and transfer cost. In our model, this relationship is not reverted-U shaped, but J shaped. Indeed, with very small transport cost, the division of labour is so high that production processes are very complex, and the need for proximity is strengthened.

The rest of the paper is organized as follows: section 1 presents a micro model of coordination cost. Section 2 introduces this micro model in a general equilibrium model of international trade. Section 3 presents the results, and especially the possibility of distance puzzle as an equilibrium.

1 Uncertainty in input-output linkages

Assume a downstream firm needs a component from an upstream firm. This component can be describe as a set of characteristics: color, material, size of the first, second (...) subcomponent, and so forth. In a world of perfect contracts, the downstream firm would be able to describe perfectly the required characteristics, and the upstream firm would build an intermediate good perfectly fitting this description. In the world of incomplete contracts New New trade theory (NNTT) focuses on, however, the downstream firm is likely to observe a distance between the optimal set of characteristics and the actual one. Let z be this distance, measured in an appropriate metrics. Clearly, z is a random variable. We assume that $g(z)$, its density fonction, follows the following exponential law:

$$g(z) = \gamma e^{-\gamma z}$$

with $z > 0$ the expected value of z is then $E(z) = 1/\gamma$. In this paper, we focus on two determinants of z : geographical distance between upstream and downstream firms, and the complexity of the production process in which the intermediate good is included. Let d be the geographical distance, and n_I the number of different varieties of intermediate goods used by the downstream firm, which is a proxy for the complexity of the production process. The expected distance $E(z)$ increases with both n_I and d :

$$\gamma = 1/\phi(n_I, d)$$

with:

$$\frac{\partial \phi(n_I, d)}{\partial n_I} > 0; \frac{\partial \phi(n_I, d)}{\partial d} > 0$$

The distance between the required characteristics and the actual ones is costly for the downstream firm. This cost is what we call 'coordination cost', even though it is not a cost meant to increase the coordination, but a cost that arises from the lack of coordination. We assume it is proportional both to the price of the intermediate p_I and to z . So, if z is expressed in a correctly chosen unit, the expected coordination cost per unit of intermediate writes $p_I \phi(n_I, d)$.

Besides this coordination cost, the downstream firms has to bear a transport cost. We assume that this transport cost is an iceberg cost, that increases the cost by $p_I \theta d$, where $\theta > 0$ is a parameter that denotes the transport technology. This means that a fall in transport cost will be modeled as a fall in θ ⁵.

Finally, the expected cost of using one unit of intermediate is $p_I (\phi(n_I, d) + \theta d + 1)$. In the subsequent, we assume that firms are risk-neutral, so we think in terms of expected values.

2 International trade

The world is made of four identical countries. Each country has one neighbor and two distant partners. The distance between two neighbors is $\underline{d} > 0$, whereas $\bar{d} = \gamma \underline{d}$ ($\gamma > 1$) is the distance between distant partners. Figure 1 pictures what such a world could look like, where the lines represent the roads between the countries.

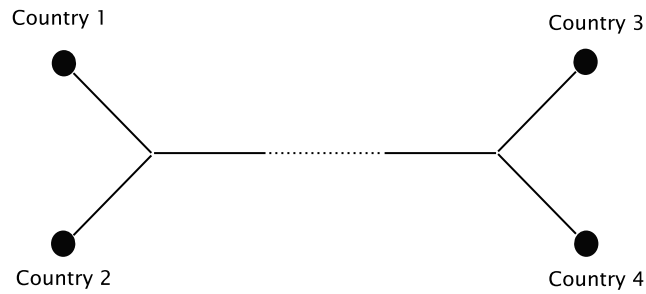


Fig. 1. The 4-country world

We choose a 4-country because a 3-country model would not allow to have a perfect symmetry between countries⁶.

⁵ since the geographical distance between two regions scarcely decreases.

⁶ In a 3-country model, either the three countries form an equilateral triangle so we can't analyze the impact of distance, either one country has to be different from the others.

In each country, a representative consumer maximizes her utility function $U = x_A^{1-\mu} X^\mu$ ($\mu \in]0; 1[$) where x_A is her consumption of an agricultural good produced with constant return to scale, and X is an industrial good. Let the agricultural good be the numeraire, P be the price of the industrial good and y the country's gdp. The budget constraint writes $y = x_A + PX$ and the optimal consumption of both goods is given by

$$\begin{aligned} x_A &= (1 - \mu) y \\ X &= \mu \frac{y}{P} \end{aligned}$$

The agricultural sector employs L_A workers. The production function is simply $x_A = AL_A$ ($A > 0$), so the wage rate is $\omega = A$. In the industrial sector, a representative firm transforms a continuum of intermediate goods into a final good, with a CES aggregator:

$$X^{(\sigma-1)/\sigma} = \sum_{k=1}^4 \int_0^{n_k} x_{i,k}^{(\sigma-1)/\sigma} di$$

where $\sigma > 1$ is the elasticity of substitution between two varieties, n_k is the number of varieties produced in country k and $x_{i,k}$ is the quantity of intermediate good of variety i produced in country k and consumed locally⁷. The firm minimizes the production cost:

$$\int_0^{n_1} x_{i,1} p_{i,1} di + \tau \int_0^{n_2} x_{i,2} p_{i,2} di + \bar{\tau} \left(\int_0^{n_3} x_{i,3} p_{i,3} di + \int_0^{n_4} x_{i,4} p_{i,4} di \right) \quad (1)$$

where $p_{i,k}$ is the price of variety i produced in country k and τ and $\bar{\tau}$ are the iceberg transfer costs for, respectively, neighbor and distant countries. Following the ideas of the previous section, we define those transfer costs as:

$$\begin{aligned} \tau &= 1 + \theta \underline{d} + \phi(N, \underline{d}) \\ \bar{\tau} &= 1 + \theta \bar{d} + \phi(N, \bar{d}) \end{aligned}$$

with $\theta > 0$ and $N \equiv \sum_{k=1}^4 n_k$. θ reflects the transport technology and N the complexity of the production process. The cost-minimization program gives the demand for an individual variety i : $x_i = (p_i \tau_i)^{-\sigma} c^\sigma X$ where τ_i is the

⁷ We do not use an index for the importing country because of the symmetry between countries.

appropriate transfer cost (that depends on the exporting country) and where:

$$c \equiv \left[\int_0^{n_1} p_{i,1}^{1-\sigma} di + \tau^{1-\sigma} \int_0^{n_2} p_{i,2}^{1-\sigma} di + \bar{\tau}^{1-\sigma} \left(\int_0^{n_3} p_{i,3}^{1-\sigma} di + \int_0^{n_4} p_{i,4}^{1-\sigma} di \right) \right]^{1/(\sigma-1)}$$

Replacing the optimal value of x_i into expression 1 gives the cost function $C(X) = cX$. Since the final good sector is competitive, the price equates the marginal cost, so $P = c$.

Each firm in the intermediate good sector produces with a fix cost f : $x_i = L_X - f$ where L_X is the number of workers employed in one such firm. The monopolistic power allows those firms to apply a markup to the marginal cost, so the price is given by:

$$p = \omega \frac{\sigma}{\sigma - 1} = A \frac{\sigma}{\sigma - 1}$$

This pricing applies for every variety in every country, so the price of the final good writes:

$$\begin{aligned} P &= \left[\frac{N}{4} \left(\frac{A\sigma}{\sigma - 1} \right)^{1-\sigma} + \frac{N}{4} \left(\frac{A\sigma}{\sigma - 1} \right)^{1-\sigma} \tau^{1-\sigma} + \frac{N}{2} \left(\frac{A\sigma}{\sigma - 1} \right)^{1-\sigma} \bar{\tau}^{1-\sigma} \right]^{1/(1-\sigma)} \\ &= \left(\frac{N}{4} \right)^{1/(1-\sigma)} \left(\frac{A\sigma}{\sigma - 1} \right) \left(1 + \tau^{1-\sigma} + 2\bar{\tau}^{1-\sigma} \right)^{1/(1-\sigma)} \end{aligned}$$

Let x^0 be the demand of a typical variety produced locally and \underline{x} and \bar{x} the demands of typical varieties produced, respectively in the neighbor country and in a distant one. Those demands write:

$$\begin{aligned} x^0 &= \left(\frac{A\sigma}{\sigma - 1} \right)^{-\sigma} P^{\sigma-1} \mu y \\ \underline{x} &= x^0 \tau^{-\sigma} \\ \bar{x} &= x^0 \bar{\tau}^{-\sigma} \end{aligned} \tag{2}$$

Since the distance puzzle is the focus of this paper, we will be interested in the impact of a fall in θ , the pure transport cost, on the ratio $\frac{\bar{x}}{\underline{x}}$, namely the ratio of distant exchange to neighbor exchange. The distance puzzle will arise in the model if this ratio decreases when θ decreases. Next section will address this question. for now, we just notice that $\frac{\bar{x}}{\underline{x}} = \left(\frac{\bar{\tau}}{\tau} \right)^{\sigma}$, so we can alternatively

focus on the ratio of both transfer costs.

Classically, in monopolistic competition, the appearance of news varieties prevents any non zero profit. This change in the number of varieties is, indeed, central in the argument of the paper. But for now, we focus on the short-run equilibrium, where N is given and thus where the profit of a typical firm can be non zero. Let π be this profit. It writes:

$$\pi = \left(x^0 + \underline{x} + 2\bar{x}\right) \left(\frac{A}{\sigma - 1}\right) - Af \quad (3)$$

Equation 3 gives the profit as a function of $x \equiv x^0 + \underline{x} + 2\bar{x}$, and equations 2 give x as a function of the gdp y ⁸. y is simply the sum of the wages earned by the workers and of the profits earned by the shareholders of the $N/4$ firms:

$$y = AL + \frac{N}{4}\pi = AL + \frac{N}{4} \left[\left(x^0 + \underline{x} + 2\bar{x}\right) \left(\frac{A}{\sigma - 1}\right) - Af \right] \quad (4)$$

Using equations 2, 3 and 4 allows to solve for x :

$$x = \frac{(\sigma - 1) \mu \left(\frac{4L}{N} - f\right)}{(B\sigma - \mu)}$$

where:

$$B \equiv \frac{\left(1 + \tau^{1-\sigma} + 2\bar{\tau}^{1-\sigma}\right)}{\left(1 + \underline{\tau}^{-\sigma} + 2\bar{\tau}^{-\sigma}\right)}$$

Finally, on equilibrium, labor demand must equate labor supply:

$$\frac{N}{4} (x + f) + L_A = L$$

3 The distance puzzle

Previous section dealt with the short-run equilibrium, where N is assumed constant and where π is allowed to be non-zero. The argument of this paper is that the fall in transport costs leads to an increased complexity of production processes, *via* an increase in N . Thus, this argument relies on the long-run

⁸ and of the price P , which is solved for since we take, for now, N as given.

equilibrium of the model, where the number of varieties N is allowed to move and where zero-profit condition applies:

$$\begin{aligned}\pi &= x \frac{A}{\sigma - 1} - Af = \frac{\mu \left(\frac{4L}{N} - f \right)}{(B\sigma - \mu)} A - Af = 0 \\ \Leftrightarrow G(N, \sigma, f, \mu, A, \theta, \phi()) &\equiv NBf\sigma - 4L\mu = 0\end{aligned}\tag{5}$$

Equation 5 defines an implicit relation between N and $(\sigma, f, \mu, A, \theta, \phi())$. We simply write $N(\sigma, f, \mu, A, \theta, \phi())$ this relation. Actually, this relation is even explicit in the special case where there is no coordination cost ($\phi() = 0$):

$$N^* \equiv N(\sigma, f, \mu, A, \theta, 0) = \frac{4L\mu}{fB\sigma}$$

Even though $\phi() = 0$ is clearly not the most interesting case, it is worthwhile to note the U-shaped relation between N^* and the transport cost parameter θ . This U-shaped relation results from two opposite effects:

- (1) a direct effect: for a given expenditure in imported industrial goods, a decrease in θ decreases the resources lost in transport, and thus increases the producer's profit, which increases N^* to restore the zero profit condition.
- (2) an indirect effect: when θ decreases, the expenditure in imported goods increases, thus the resources lost in transport can increase, with a negative impact on N^* .

Clearly, when $\theta \rightarrow \infty$, the expenditure in imported goods is virtually nil, so the second effect is stronger, whereas when $\theta \rightarrow 0$, the first one dominates.

Of course, the link between θ and N is much more complex when $\phi() > 0$, since in this case, N is present in B . However, qualitatively, we already can figure out the difference between our model and Duranton & Storper's, keeping in mind that N denotes the complexity of the production process which is the source of the coordination cost. Whereas the coordination cost tends to vanish for low values of the transport cost, it tends to strengthen in our model.

Now, to be rigorous, we should prove that the above mentioned phenomenon can indeed arise in the model, when $\phi > 0$. The implicit function theorem applied to equation 5 allow to write the marginal effect of θ on N :

$$\left. \frac{\partial N}{\partial \theta} \right|_{\pi=0} = - \frac{\partial G(\cdot)/\partial \theta}{\partial G(\cdot)/\partial N} = - \frac{\partial B/\partial \theta}{(B/N + \partial B/\partial N)}$$

Parameter	value
σ	3
μ	0.5
A	1.2
L	20
f	μ/σ

Table 1
Parameters

This effect depends on $\partial B/\partial \theta$ and $\partial B/\partial \theta$, which write:

$$\frac{\partial B}{\partial \theta} = \underline{d} \frac{(1 - \sigma) \left(\underline{\tau}^{-\sigma} + \gamma 2 \bar{\tau}^{-\sigma} \right) \left(1 + \underline{\tau}^{-\sigma} + 2 \bar{\tau}^{-\sigma} \right) + \sigma \left(1 + \underline{\tau}^{1-\sigma} + 2 \bar{\tau}^{1-\sigma} \right) \left(\underline{\tau}^{-\sigma-1} + \gamma 2 \bar{\tau}^{-\sigma-1} \right)}{\left(1 + \underline{\tau}^{-\sigma} + 2 \bar{\tau}^{-\sigma} \right)^2}$$

$$\frac{\partial B}{\partial N} = \frac{(1 - \sigma) \left(\frac{\partial \phi(N, d)}{\partial N} \underline{\tau}^{-\sigma} + \frac{\partial \phi(N, \bar{d})}{\partial N} 2 \bar{\tau}^{-\sigma} \right) \left(1 + \underline{\tau}^{-\sigma} + 2 \bar{\tau}^{-\sigma} \right) + \sigma \left(1 + \underline{\tau}^{1-\sigma} + 2 \bar{\tau}^{1-\sigma} \right) \left(\frac{\partial \phi(N, d)}{\partial N} \underline{\tau}^{-\sigma-1} + \frac{\partial \phi(N, \bar{d})}{\partial N} 2 \bar{\tau}^{-\sigma-1} \right)}{\left(1 + \underline{\tau}^{-\sigma} + 2 \bar{\tau}^{-\sigma} \right)^2}$$

Those expressions are not very tractable, but $\frac{\partial B}{\partial \theta}$ can be either positive or negative. Hereafter, we focus on the case where $\frac{\partial B}{\partial \theta} \geq 0$.

The distance puzzle arises, in this model, if a fall in θ results in an increase in $\frac{x}{\bar{x}}$, or equivalently, in an increase in $\frac{\bar{\tau}}{\underline{\tau}}$. Again, no clear result can be expressed

about the sign of $\partial \left(\frac{\bar{\tau}}{\underline{\tau}} \right) / \partial \theta$, except that it can be either positive or negative.

To illustrate this point, we perform simulations with $\phi(N, d) = \phi N d^2$ ($\phi \geq 0$) and the parameters given in table 1.

Figures 2 and 3 represent, respectively, the number of varieties and the ratio $\frac{x}{\bar{x}}$ as functions of theta, for three different values of ϕ : 0, 0.001 and 0.005. In all three cases, the number of varieties increases when $\theta \rightarrow 0$, even if higher values of ϕ lowers the slope of the curve⁹. When $\phi = 0$, the increasing complexity does not impact trade, since this case corresponds to the absence of coordination cost. So, when $\theta \rightarrow 0$, full economic integration is achieved, and the ratio of neighbor to distant exchange tends to 1. For a small value of ϕ (0.001), the increasing complexity prevents full economic integration: distance

⁹ Actually, simulations performed with even higher values of ϕ result in decreasing number of firms.

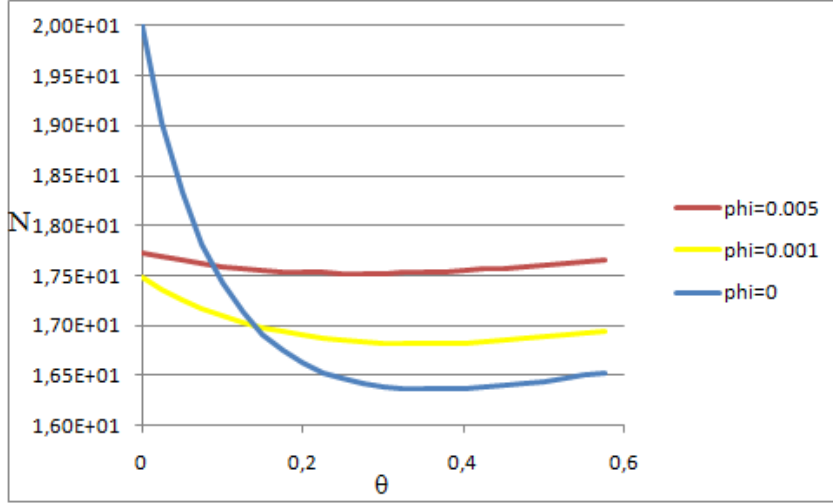


Fig. 2. N as function of θ

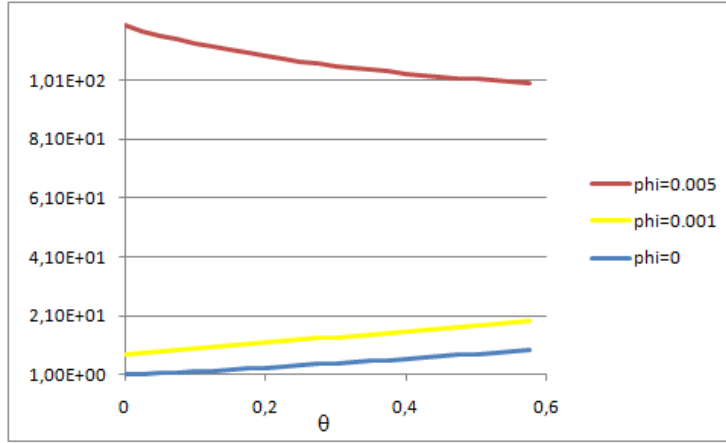


Fig. 3. The ratio $\frac{x}{\bar{x}}$ as function of θ

matters less, but still matters when $\theta \rightarrow 0$. Finally, with a high value for ϕ (0.005), coordination cost is high enough to revert the slope of the curve of $\frac{x}{\bar{x}}$: distance matters more with low transport cost. This is the distance puzzle! Goods are less expensive to trade, more varieties are traded, division of labor is increased. But this increased division of labor increases the need of coordination, that in turn increases the importance of distance.

Concluding remarks

In this paper, we wanted to add a theoretical explanation of the distance puzzle. We argue that the introduction of coordination, accounting for contract incompleteness between upstream and downstream firms, helps to explain this puzzle. As we explain in the introduction, our model shares both similarities

and differences with Duranton and Storper's (2008).

The main similarities are i) the contract incompleteness and ii) the non monotonic relationship between the pure transport cost and the global transfer cost. In both models, a fall in transport cost allows an improvement in the production process, but due to contract incompleteness, this improvement results in an increased transfer cost.

The main differences are i) the mechanism of the improvement of the production process: it comes from an increased quality in Duranton and Storper, whereas in the present paper, it comes from an increased international division of labor, and thus an increased complexity. ii) the nature of the non monotonicity is reverted: in Duranton and Storper, the relation is reverted-U shaped, whereas it is J shaped in our model. This difference is somehow fundamental, because the predicted effect of a fall in transport cost in both models are opposite for small transport costs. If $\theta \rightarrow 0$ is considered as the long run tendency, then both models have opposite long run predictions. Basically, Duranton and Storper's result strongly depends on the common modeling of transaction cost and transport cost. They assume that the loss due to transport is proportional to quality of the traded intermediates. High quality goods are more expensive to trade, because, they argue, more coordination is needed for those goods. But a direct consequence of this assumption is that a zero transport cost leads to a zero transaction cost. So, the main difference with our model is that we consider two specific functions: one for transport, one for the coordination cost. When the former is zero, the second needs not be nil.

In this respect, confronting both results leads to a question that is more fundamental than the one of the choice between quality and labor division as the cause of coordination problems: should we believe that globalization has the same effect to transport cost and to coordination cost? If the answer is yes, then Duranton and Storper are right to consider that, on the long run, it will finally lead to a death of distance. If it is no, then the increasing complexity of production processes allowed by the globalization may, paradoxically, lead to a distance revival.

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