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Noblet, Sandrine and Belgodere, Antoine

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Sandrine Noblet, Antoine Belgodere [1,2,3]

Abstract

Since 1960, transport costs have been falling, but international exchange did not become less sensitive to distance. We propose the following explanation for this puzzle: in a *Dixit-Stiglitz* framework, a decrease in transport cost favors trade, which may increase the international specialization (*i.e.* the number of varieties of intermediate goods used in production). An increased international specialization increases the need for coordination, and makes relatively more important for downstream firms to be close to their suppliers. As a result, trade increases with all partners, but more quickly for neighbors than for distant countries.

Key words:
Transport cost, coordination cost, international trade, distance puzzle

JEL Classification: F12, F15

Introduction

The distance puzzle has been widely discussed in the literature since Leamer and Medberry (1993) shed light on it. This puzzle simply says that "the world is not getting smaller": distance still matters to account for trade despite declining trade costs. There are two measures to quantify the impact of distance on trade: elasticity of trade to distance and the distance of trade (DOT). The most commonly used is elasticity of trade to distance derived from the standard gravity equation. The second measure, proposed by Carrère and Schiff

[1] Phd Student, Université de Corse - UMR CNRS LISA 6240. Email: noblet@univ-corse.fr
[2] Associate professor (Maître de Conférence), Université de Corse - UMR CNRS LISA 6240. Email: belgodere@univ-corse.fr
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(2005), is defined as an average distance between trade partners weighted by trade volumes. One would expect globalization to result in a decreasing sensitivity of trade to distance *i.e.* decreasing distance coefficient and increasing DOT over time. However, most studies show increasing or constant distance coefficients (among others Leamer and Medberry (1993), Brun et al. (2005), Disdier and Head (2008), Berthelon and Freund (2008)) and decreasing or constant trends of DOT over these last decades (Carrère and Schiff (2005), Berthelon and Freund (2008)).

Several explanations have been proposed in the literature which can be classified into 5 categories, related to : 1) the interpretation of the distance coefficient, 2) changes in the geography of production, 3) the multiplication of Regional Trade Agreements (RTA), 4) the compositional effect and 5) the emergence and the evolution of different components of trade costs, defined in a broader way than pure transport costs.

Our paper contributes to this literature by proposing a new theoretical explanation to this puzzle, that belongs to the fifth category. More precisely, our explanation is in line with the one developed by Duranton and Storper (2008). They show that the increased sensitivity of trade to distance can emerge from a fall in transport through a *quality effect*. They show that a fall in transport costs provides firms with incentives to produce higher quality goods and they assume that higher quality are more expansive to exchange. This latter assumption is related to the idea that within an incomplete contract environment, the exchange of higher quality goods requires more coordination between the supplier and the buyer. As a result, the relationship between pure transport costs and global transfer costs (including coordination costs) is non monotonic. On the decreasing part of this relationship, a fall in transport costs increases the need of proximity with the firm's suppliers.

The explanation presented in this paper shares with Duranton and Storper's two important characteristics: i) the relationship between transport cost and trade cost is not necessarily monotonic, ii) this phenomenon arises from 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 costs may increase the international division of labor. In this framework, the increasing international division of labor can be interpreted as an increasing specialization of intermediate goods. As a consequence, we assume that production processes become more complex (this is the *complexity effect*), which in turn implies 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. Contrarily to Duranton and Storper's, our model predicts an increase in the distance puzzle in the long run (*i.e.* for low transport costs).

The rest of the paper is organized as follows: section 1 presents and discusses several attempts to solve this puzzle, section 2 presents a micro model of coordination cost, section 3 introduces this micro model in a general equilibrium model of international trade, section 4 presents the results, and especially the possible emergence of distance puzzle at the equilibrium. The final section concludes.

1 Is the distance puzzle still puzzling?

In this section, we present and discuss several attempts to solve the distance puzzle, following the 5 categories presented in introduction [4].

The interpretation of the distance coefficient:

Coe et al. (2002) highlight two different interpretations of the distance coefficient which could explain the trend of estimated distance coefficient. The first interpretation is based on the basic definition of the distance coefficient in gravity equation since Deardoff (1998) and Anderson & van Wincoop (2001). Following this definition, the distance coefficient is the product of the elasticity of trade to trade costs with the elasticity of trade costs to distance, and the latter is equal to the ratio of marginal trade cost to the average one. Then, the constant trend of distance coefficient could be explained by a proportional fall in both marginal and average trade costs and, similarly, the increasing trend (in absolute value) would be explained by a deeper fall in marginal trade costs than average costs. However, as pointed out by Coe et al. (2002), data on transport costs does not allow to differentiate these two components of transport costs, making its empirical validation difficult to assess.

The second interpretation of the distance coefficient states that not only bilateral trade costs matter but also trade costs between all others potential partners. Indeed, if transport costs with neighbor countries fall relatively more than transport costs with distant countries, then transport costs would favor trade with neighbors. The basic way to account for this effect is in introducing a multilateral resistance term [5]. However, according to Coe et al. (2002), this effect does not seem to explain the distance puzzle, suggesting that transport costs with distant countries have fall more than transport costs with neighbors ones. Despite this latter result, Brun et al. (2005) show that it allow to reduce the scope of the distance puzzle [6]. Finally, Buch et al. (2004) argue

[4] We leave aside the methodological aspect of the debate. See, for instance, Coe et al. (2007) and Archanskaia and Daudin (2010).

[5] Since the seminal papers of Deardorff (1998) and Anderson and van Wincoop (2003) on this issue.

[6] For instance, introducing the multilateral resistance term, Brun et al. (2005)

that distance coefficient in gravity equations should be interpreted in terms of changes in distance costs. They explain the stable trend of distance coefficient over time by a proportional fall in distance costs. However, this explanation implies that trade costs are linear to distance which seems to be invalidate by the fact that transport costs with distant countries have fallen more than transport costs with neighbor ones (Dias (2010)). Moreover, a proportional fall in trade cost does not mean a proportional fall in the transport cost parameter, which is equal to the *ad valorem* trade cost plus one. Basically, if the transport cost parameter is 2.2 for a distant country and 1.1 for a neighbor country, then a proportional fall in transport cost means that the new coefficients must be, *e.g.*, 1.6 and 1.05, and not 1.6 and 0.8. So the ratio of both parameters tends to 1 when transport costs keep on falling.

The evolving geography of production:

Leamer and Levinsohn (1995) have been the first to suggest that the dramatic increase in trade flows could be due to a more dispersed repartition of GDP around the world rather than to a dramatic fall in transport costs. It follows that the constant distance coefficient is not puzzling, because the increase in global trade does not reveal a fall in transport costs. However, evidence from Hummels (2007) indicates that *ad valorem* transport costs have experienced a fall of about 25% between 1974 and 2004. This should indeed have made trade less sensitive to distance.

More recently, a few studies have tried to explain the trend of DOT with a similar argument. For instance, Carrère and Schiff (2005) showed that distance of trade (DOT) within countries of South-East Asia have sharply decreased while several countries in the neighborhood has been developing. Finally, Berthelon and Freund (2008) have provided theoretical estimation of DOT, between 1985 and 2005, in a frictionless world, in order to account for the impact of dispersion of economic activities on DOT. They show[7] that actual DOT are significantly correlated with theoretical ones but they are also significantly smaller, suggesting that, given changes in GDP over the period, DOT should have increased more than it did.

The impact of Regional Trade Agreements:

Another way to look at the distance puzzle is to analyze the impact of Regional Trade Agreements (RTA) on DOT. Indeed, trade agreements enhance trade between countries that are geographically close (since those agreements are usually settled between neighbors), then it could lower DOT of countries without reflecting an increasing sensitivity of goods to distance. This effect was

observe constant distance coefficient between 1962 and 1996 rather than decreasing without this latter effect.

[7] See Berthelon and Freund (2008) Fig. 1, pp.314.

studied by Carrère and Schiff (2005) for eight free trade area for the period 1962-2000. They found an average effect of RTA on the trend of DOT equal to -0.20%. However, they also highlighted that the share of countries experiencing an increase in DOT is twice larger inside those trade blocs. On the other hand, when Coughlin (2004) studied the impact of NAFTA on Amercian trade flows, he noted that since the creation of NAFTA, while amercian exports with NAFTA members (*i.e.* Canada and Mexico) have increased. The same applied for Asian countries, whereas exports with non-member Latin-American countries decreased despite their geographical proximity. They suggest that these changes in Amercian exports are not only due to NAFTA creation but also to economic growth. Indeed, during this period Canada, Mexico and Asia were among fastest growing countries in the world whereas Latin America were not (Coughlin (2004)). Archanskaia and Daudin (2010) argue that controlling for the RTA can explain the distance puzzle. Indeed, using a balanced panel of trading partners [8] they show that RTA could explain the puzzle. However, as suggested by authors estimation of RTA can be biased because of the potential endogeneity of RTA (Fontagné and Zignago (2007)).

The compositional effect:

The fourth explanation is related to a compositional effect: 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) suggest this effect could explain 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% sectors [9]. Siliverstovs and Schumacher (2008) have also investigated the distance puzzle at both aggregate and disaggregate levels. They show that while the distance puzzle holds using aggregate data, it does not at a disaggregate level, suggesting that changes are compensated at the aggregate level. Thus, the compositional effect seems to explain the puzzle. However, differences between these two papers could come from the fact that the country sample used by the latter is smaller (22 for the latter vs 73 for the former) and composed of more homogeneous countries, as emphasized by Siliverstovs and Schumacher (2008). Archanskaia and Daudin (2010) provide estimation controlling for the compositional effect. This effect appears to explain a decrease of trade elasticities over time, while, at the aggregate level, trade elasticities are constant.

[8] This balanced panel of trading partners allow them to control for the creation of new countries in the nineties following the dissolution of USSR.

[9] They linked this increased coefficient with the level of substituability of goods: homogenous goods are more sensitive to the distance than differentiated ones.

On the evolution of different components of trade costs:

Grossman (1998) argues that trade elasticities are too important in magnitude to account only for transport costs. This suggests that trade costs have to be defined in a broader way in order to encompass other components that affect trade and follow different patterns [10].

In Brun et al. (2005) trade costs encompass the real oil price, the level of infrastructure and the real exchange rate, and allow them to find decreasing elasticities of trade to distance of about 11% between 1962 and 1996. However, this evidence of globalization appears to be limited to "rich countries". Dias (2010) obtains similar conclusion despite the different framework used. Indeed, he proposed to account for three distinct aspects of globalization *i.e.* changes in transport costs, unrelated-distance trade costs (proxied by tariffs) and barriers to production decentralization (proxied by FDI). He concludes that unrelated-distance trade costs has the most significant impact on distance elasticity, suggesting that a fall in unrelated-distance trade costs favors more remote countries whereas a fall in trade costs related to distance favors countries that have more central geographical position.

Krautheim (2007) and Duranton and Storper (2008) differ in their explanation from the previous in the fact that other components of transfer costs can evolve endogenously is response to an improvement in transport technology. Specifically, Krautheim (2007) considered that information affects exportations. Within a framework of heterogeneous firms, he introduces the possibility for firms, within a country, to create a network in order to facilitate the exchange of information. Then, trade flows are affected to distance through two different mechanisms: 1) firms engaged in trade with closer countries experienced higher trade flows (this is the *intensive margin*), and 2) lower distance between two countries $\{i, j\}$ increases the number of firms exporting from i to j (this is the *extensive margin*). Creation of informational network allows to explain both the high level of trade elasticities and their increase through the following mechanism: exogenous increase in network quality creates more incentives for firms to export with all its partners but relatively more with its closer partners than its distant ones. As a consequence, trade elasticities increase.

Duranton and Storper (2008) propose an alternative explanation that accounts

[10] Notice that several papers highlight the emergence of new constraints in trade which could counterbalanced the fall in transport costs. Among them, Hummels (2001) reported that each day spent in transit reduced the value of merchandise of about 0,8%, Fink et al. (2005) estimated that a halving of communication costs (proxied bilateral calling price) could lead to a 42.5% increase in bilateral trade. On the other hand, Stein and Daude (2007) observed that differences in time zones appear to reduce trade and FDI.

for the exchange of information but with respect to intermediate goods characteristics. 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 labor used in the production of the machine. If the willingness to pay for a 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. Transfer cost is simply 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. Within this framework, the distance puzzle would only apply for high transport costs. As a result, the long-run prediction of this model is that this puzzle will disappear if $\zeta \to 0$.

Our model tells a similar story than Duranton and Storper's. However it differs with respect to the nature of the relationship. Similarly to Duranton and Storper, we find that the relationship between transport cost and transfer cost is non necessarily monotonic. However, our model differs in terms of long run prediction. Indeed, we show that the distance puzzle could be strengthened for very low level of transport cost.

2 Coordination cost 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 function, follows the following exponential law:

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

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 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 and d:

$$\gamma = 1/\phi\left(N,d\right)$$

with:

$$\frac{\partial \phi\left(N,d\right)}{\partial N} > 0; \frac{\partial \phi\left(N,d\right)}{\partial d} > 0$$

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 $p_I \phi\left(N,d\right)$.

Besides this coordination cost, the downstream firms have 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 [11] .

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

3 International trade

The world is composed of four identical countries. Each country has one neighbor and two distant partners. The distance between two neighbors is $\underline{d} > 0$, whereas $\overline{d} = \gamma \underline{d}$ $(\gamma > 1)$ 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.

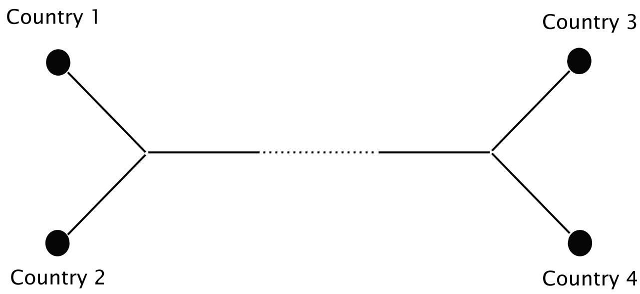

Fig. 1. The 4-country world

[11] since the geographical distance between two regions scarcely decreases.

We choose a 4-country because a 3-country model would not allow to have a perfect symmetry between countries [12].

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

$$x_A = (1-\mu)\, y$$
$$X = \mu \frac{y}{P}$$

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 locally [13]. The firm minimizes the production cost:

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

where $p_{i,k}$ is the price of variety i produced in country k and $\underline{\tau}$ 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:

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

[12] 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.

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

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

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

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:

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

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:

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

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 $\frac{\bar{x}}{\underline{x}} = \left(\frac{\underline{\tau}}{\bar{\tau}}\right)^{\sigma}$, 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:

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

Equation 3 gives the profit as a function of $x \equiv x^0 + \underline{x} + 2\bar{x}$, and equations 2 gives x as a function of the gdp y[14]. 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:

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

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:

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

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

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

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

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

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

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

$$N* \equiv N(L,\sigma,f,\mu,A,\theta)\Big|_{\phi(N,d)=0} = \frac{4L\mu}{fB\sigma}$$

Even though $\phi()=0$ is clearly not the most interesting case, it is worthwhile to note the U-shaped relationship between $N*$ and the transport cost parameter θ. This U-shaped relationship 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 $\theta \to \infty$, the expenditure in imported goods is virtually nil, so the second effect is stronger, whereas when $\theta \to 0$, 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 allows to write the marginal effect of θ on N:

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

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

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

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

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

The distance puzzle arises, in this model, if a fall in θ results in an increase in $\frac{\underline{x}}{\bar{x}}$, or equivalently, in an increase in $\frac{\bar{\tau}}{\underline{\tau}}$. The sign of $\partial\left(\frac{\bar{\tau}}{\underline{\tau}}\right)\Big/\partial\theta$, is the same as the sign of $\frac{\partial \bar{\tau}}{\partial \theta}\underline{\tau} - \frac{\partial \underline{\tau}}{\partial \theta}\bar{\tau} = \left(\bar{d} + \frac{\partial N}{\partial \theta}\frac{\partial \phi\left(N,\bar{d}\right)}{\partial N}\right)\underline{\tau} - \left(\underline{d} + \frac{\partial N}{\partial \theta}\frac{\partial \phi\left(N,\underline{d}\right)}{\partial N}\right)\bar{\tau}$. This expression shows that the impact of a fall in θ on $\frac{\underline{x}}{\bar{x}}$ is undetermined. In other words, in this model, *the distance puzzle can arise.*

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

Table 1
Parameters

Parameter	σ	μ	A	L	f	$\underline{d}$	$\bar{d}$
value	3	0.5	1.2	20	μ/σ	1	4

Figures 2 and 3 represent, respectively, the number of varieties and the ratio $\frac{\underline{x}}{\bar{x}}$ as functions of θ, for three different values of ϕ: 0, 0.001 and 0.005. In all three cases, the number of varieties increases when $\theta \to 0$, even if higher values of ϕ lowers the slope of the curve [15] . When $\phi = 0$, the increasing complexity does

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

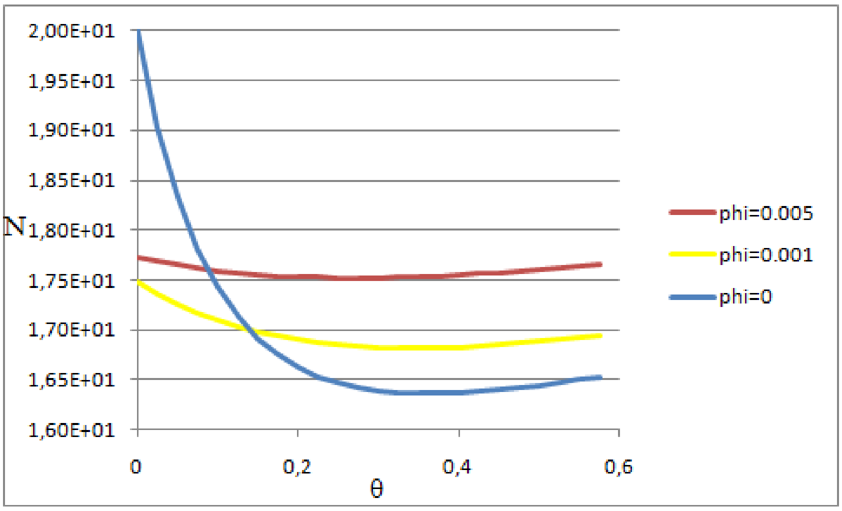

Fig. 2. N as function of θ

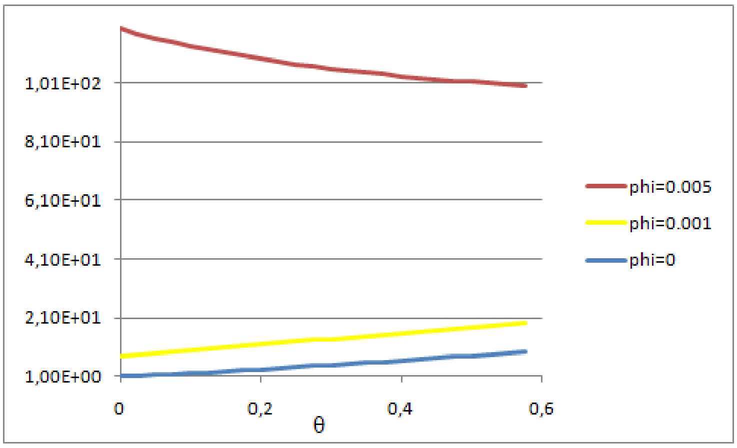

Fig. 3. The ratio $\frac{x}{\bar{x}}$ as function of θ

not impact trade, since this case corresponds to the absence of coordination cost. So, when $\theta \to 0$, 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 matters less, but still matters when $\theta \to 0$. 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 expansive 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 wrote in section 1, 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 transport cost and the coordination 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 U or 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 $\theta \to 0$ 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.

References

Anderson, J. E., van Wincoop, E., 2003. Gravity with gravitas: A solution to the border puzzle. American Economic Review 93 (1), 170–192.

Archanskaia, E., Daudin, G., 2010. Trade elasticities and the distance puzzle, preliminary version, presented at the l'Eastern Economic Association, feb. 2010, Philadelphia.

Berthelon, M., Freund, C., 2008. On the consevration of distance in international trade. Journal of International Economics 75, 310–320.

Brun, J.-F., Carrère, C., Guillaumont, P., de Melo, J., 2005. Has distance died? evidence from a panel gravity model. World Bank Economic Review 19 (56), 99–120.

Buch, C. M., Kleinert, J., Toubal, F., 2004. The distance puzzle: on the interpretation of the distance coefficient in gravity equations. Economics Letters 83 (3), 293–298.

Carrère, C., Schiff, M., 2005. On the geography of trade: distance is alive and well. Revue Economique 6 (56), 1249–1274.

Coe, D. T., Subramanian, A., Tamirisa, N. T., 2007. The missing globalization puzzle: evidence of the declining importance of distance. IMF Staff Papers 1 (54), 34–58.

Coe, D. T., Subramanian, A., Tamirisa, N. T., Bhavnani, R., 2002. The missing globalization puzzle. IMF Working Papers 02/171, International Monetary Fund.

Coughlin, C. C., 2004. The increasing importance of proximity for exports from u.s. states. Federal Reserve Bank of St. Louis Review 86, 1–18.

Deardorff, A., 1998. Determinants of bilateral trade: Does gravity work in a neoclassical world? In: Frankel, J. A. (Ed.), The Regionalization of the World Economy. University of Chicago Press for the NBER, pp. 7–32.

Dias, D. A., January 2010. Gravity and globalization, mimeo UCLA.

Disdier, A.-C., Head, K., 09 2008. The puzzling persistence of the distance effect on bilateral trade. The Review of Economics and Statistics 90 (1), 37–48.

Duranton, G., Storper, M., February 2008. Rising trade costs? agglomeration and trade with endogenous transaction costs. Canadian Journal of Economics 41 (1), 291–319.

Fink, C., Mattoo, A., Neagu, I. C., 2005. Assessing the impact of communication costs on international trade. Journal of International Economics 67 (2), 428–445.

Fontagné, L., Zignago, S., 2007. A re-evaluation of the impact of regional agreements on trade patterns. Economie Internationale / International Economics 109, 31–51.

Grossman, G. M., 1998. The regionalization of the world economy. University of Chicago Press for the NBER, Ch. Comment on Deardorff.

Hummels, D., 2007. Transportation costs and international trade in the second era of globalization. Journal of Economic Perspectives 21 (3), 131–154.

Hummels, D. L., 2001. Time as a trade barrier. GTAP Working Papers 1152, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.

Krautheim, S., 2007. Gravity and information: Heterogeneous firms, exporter networks and the 'distance puzzle'. Economics Working Papers ECO2007/51, European University Institute.

Leamer, E. E., Levinsohn, J., 1995. International trade theory: The evidence. In: Grossman, G. M., Rogoff, K. (Eds.), Handbook of International Economics. Vol. 3. Elsevier, Ch. 26, pp. 1339–1394.

Leamer, E. E., Medberry, C. J., 1993. U.s. manufacturing and an emerging mexico. NBER Working Papers 4331, National Bureau of Economic Research, Inc.

Siliverstovs, B., Schumacher, D., 2008. Disaggegated trade flows and the "missing globalization puzzle". Economie Internationale / International Economics 115, 141–164.

Stein, E., Daude, C., 2007. Longitude matters: Time zones and the location of foreign direct investment. Journal of International Economics 71 (1), 96–112.