Gravity and Globalization: A Re-interpretation of Old Results*

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Abstract

This paper addresses the puzzling empirical result regarding the persistent, and in some cases increasing, effect of distance on international trade. In particular, it shows how globalization can reconcile a decrease in transportation costs and an increase in the impact of distance on trade, which is usually estimated in the context of a gravity equation. The key argument is the following: the process of globalization is a mix of reduction in transportation costs and of openness to foreign investment. The combination of these two facts lead to a situation in which, not only it became cheaper to move products from one country to another (transportation costs effect) but it also became cheaper to decentralize the production. The net impact of the two forces is undetermined.

JEL classification codes: C20, F10, F23.
Key Words: Trade, Gravity, Globalization.

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1. INTRODUCTION

A well established empirical result in the trade literature is that, over time, the coefficient of distance in the context of a gravity equation has increased or at least it has not decreased. For instance, Disdier and Head (2008) survey more than 100 papers and conclude that the coefficient of distance rose in the middle of the century and it was kept persistently high since then. This empirical regularity is seen as puzzling since in the last four to five decades the world has become more globalized and therefore distance should matter less. In this paper, I claim that this line of thought does not have a theoretical background. First, as transportation costs fall, distance does not become less important for all countries. Second, because globalization should be seen as more than just a reduction in transportation costs, by extending the concept of globalization to incorporate changes in the incentives that firms face to have multinational operations, I show that once again the impact of distance on trade could have increased or decreased.

The mechanism by which this outcome is very intuitive. As the World becomes more globalized, firms have more opportunities of where to invest and of where to produce their products. This means that firms now face two alternatives, they either produce everything locally and ship products to the markets of interest or they decentralize their production in order to minimize the transportation costs and increasing the size of their markets. Because of this process, distance may become more costly as more alternatives to shipping exist. One key assumption is that products can be produced anywhere in the World, which for a vast majority of items it is a very mild assumption.

To my best knowledge, this paper is one of the first attempts to link multinational firm activities to the geography of trade. The idea that changes in capital controls and/or better enforcement of intellectual property rights, vis-a-vis changes in production decentralization incentives, lead to an increase of activities of multinational firms is known. Lee and Mansfield (1996) show that US FDI increases in a country where protection of intellectual property rights is improved; Desai Foley and Hines (2006) show that capital controls liberalizations are associated with significant increases in multinational activity.
A good illustration of this mechanism is the exports of autos from Japan. Initially, Japan produced all the cars it exported but, nowadays, many of the cars sold by Japanese car manufacturers are produced outside of Japan. This substitution between local production for decentralized production would be reflected in a gravity model with an increase of the impact of distance, while the only thing that happened was that production was re-organized.

It is important to mention that paper is not the first attempting to explain why distance became more important over time. Two examples of alternative explanations are given in Coe et al (2007) and Berthelon and Freund (2008). Coe et al (2007) argue that the problem comes from the estimation method. In this work, the authors use a non-linear estimation method to estimate the gravity equation, and they obtain estimates for the coefficient of distance that decrease over time while the same does not happen when using the more standard linear estimation methods (OLS). In the second example I mentioned previously, Berthelon and Freund (2008), it is claimed by the authors that the coefficient of distance increased over time due to either a compositional bias or to higher competition. That is, different products have different elasticities of distance and therefore the resulting estimate is a weighted average of all the different elasticities. If for some reason, trade grew more for industries with higher elasticities of distance, then the resulting estimate would be biased in favor of higher distance elasticities. Alternatively, it could have been the case that some products faced a larger increase in competition than others and consequently these products saw their elasticity of distance increase more.

The remainder of the paper is organized as follows: in section 2 I use an extension of the Eaton and Kortum (2002) model proposed by Dias and Richmond (2009) which allows for the existence of decentralized production to show how a reduction in transportation costs indeed should reduce the effect of distance but also that changes in the incentives to decentralize production can increase or decrease the impact of distance; in section 3 I describe the data, discuss some of the econometric problems that involve estimating a gravity equation, and empirically test some of the propositions derived in section 2; finally, in section 4 I conclude.
2. THE MODEL

The extension of the Eaton and Kortum (2002) that was proposed by Dias and Richmond (2009) is very simple and it has the nice features of not only having a closed form solution but also it encompasses the E&K model as a particular case. The central idea of this extension of the model is that instead of considering that a country $i$ can only use its technology produce product $j$ in country $i$, they extend the production possibilities to all other countries. That is, a firm in country $i$ has a specific productivity to produce product $j$ and, by paying a certain cost, it can now also use this technology in all other countries. This implies that when a firm is competing with other firms to export to a certain country, now it has a much wider range of places where it can produce and with that minimize the impact that transportation costs have on its competitiveness.

The setup of the model follows very closely the E&K formulation. Like in E&K it’s assumed Bertrand competition, iceberg type transportation costs, CRS production technology, random productivity shocks and taste for variety. The novelty is that it is now possible to separation between the country where the product is produced and the country that owns the right to the value of that production. This is made by allowing that each country receives a productivity draw to produce the good in each one of the $N$ different countries. This means that if there are $N$ countries, there will be $n \times n$ productivity draws for each $j$ product, one for each possible combination of owner and producer country. As in E&K it is assumed that countries differ from each other with respect to their overall productivity level, that is, with the respect to the location parameter in the productivity distribution. A very important parameter in this extension of the model is the parameter that measures the cost of producing abroad, this parameter is $\tau \in [0, 1]$. Basically $\tau$ will affect the overall technological level of country $i$ when country $i$ decides to produce in a foreign country. That is, if country $i$ has a technology parameter equal to $T_i$ we assume that if country $i$ produces product $j$ in country $k$, its overall productivity will be discounted by a factor $\tau \in [0, 1]$. If $\tau$ is equal to 0 it means that if country $i$ produces product $j$ in country $k$ it will lose all the value of that good, whereas if $\tau$ is equal to 1, country $i$ has no cost of producing in country $k$. 
As it is show in Dias and Richmond (2009), the E&K model is equivalent to assuming \( \tau = 0 \).

To be more specific about the assumptions are being made, let:

- \( i = 1, \ldots, N \) denote the country where production takes place;
- \( k = 1, \ldots, N \) denote the country that owns the production;
- \( T_{i,k} \) denote the overall technological development of country \( k \) when production takes place in country \( i \). In this formulation, if \( i = k \) then \( \tau = 1 \);
- \( c_i \) denote the marginal cost of producing one unit in country \( i \) (notice that this unitary cost does not depend on the country that owns the production but only on the country where production takes place);
- the iceberg transportation costs are a function of distance and of the unitary transportation cost, \((1 + \delta_{ni}d) > 1\) denotes the cost of transporting one unit of a given product produced in country \( i \) into country \( n \). The parameter \( \delta_{ni} \) measures the distance between and \( d \) denotes the unitary transportation cost (the advantage of separating the transportation cost into distance and unitary cost is that it is now possible to determine the trade elasticity of distance in the context of this model);
- \( j \in [0, 1] \) denotes a given product from a continuum of products;
- \( z_{i,k}(j) \), which has C.D.F. \( G(z_{i,k}(j)) = \exp \left\{ -T_{i,k}T_{i,k}(z_{i,k}(j))^{-\theta} \right\} \), with \( \theta > 1 \), denotes the productivity that country \( k \) has in producing product \( j \) in country \( i \). Like in E&K (2002) it is assumed that \( z_{i,k} \) is independent across \( i \) and for modelling simplification purposes it is also assumed that the productivity shocks are independent across \( k \).

In deciding which country exports product \( j \) to country \( n \) there are two layers of decision: 1) each country \( k \), decides which country \( i \) will serve country \( n \) among all possible sources of production; and 2) given the previous choices it is necessary to find
which one is able to serve country $n$ with the lowest price. What makes this problem very simple is that it is equivalent to finding the minimum price among all possibilities.

As it is shown in Dias and Richmond (2009), the distribution of prices in country $n$ is:

$$G_n(p) = 1 - \exp \left( -p^\theta \sum_{i=1}^{N} \left\{ (c_i (1 + \delta_{ni}d))^{-\theta} \left( \sum_{k=1}^{N} T_{i,k} \tau_{i,k} \right) \right\} \right)$$

$$= 1 - \exp \left( -p^\theta \sum_{i=1}^{N} \left\{ (c_i (1 + \delta_{ni}d))^{-\theta} \tilde{T}_i \right\} \right).$$

Equation (1) corresponds to the combination of equations (6) and (7) in E&K (2002), with $\tilde{T}_i$ in this notation corresponding to $T_i$ in their notation. The difference being that $\tilde{T}_i = \sum_{k=1}^{N} T_{i,k} \tau_{i,k}$, which in this case represents the technological state of the exports from country $i$ but not the technological state of country $i$ in general, as it happens in E&K. It is easy to see that if $\tau_{i,k} = 1$ if $i = k$ and 0 otherwise, the extension we propose, corresponds exactly to the E&K model. Under these assumptions, all other results from E&K follow naturally with the only difference coming from the technology parameters.

Based on this result I can now use the equations that measure the share of exports that country $n$ imports from country $i$ directly from E&K (2002) and replace all parameters $T_i$ with $\tilde{T}_i$ in order to derive the distance elasticity. This expression is as follows:

$$\frac{X_{ni}}{X_n} = \frac{\tilde{T}_i (c_i (1 + \delta_{ni}d))^{-\theta}}{\Phi_n} = \frac{\tilde{T}_i (c_i (1 + \delta_{ni}d))^{-\theta}}{\sum_{j=1}^{N} \tilde{T}_j (c_j (1 + \delta_{nj}d))^{-\theta}}.$$  (2)

The exports elasticity of distance for country $i$ can be defined as the percentage change in exports from country $i$ to country $n$ if the distance between the two countries increased by 1% while the distances between country $n$ and all other countries $j = 1, ..., N$ and $j \neq i$ did not change. The expression for the elasticity of distance is the following:

$$\varepsilon_{ni} = \frac{\partial \left( \frac{X_{ni}}{X_n} \right)}{\partial \delta_{ni}} \frac{\delta_{ni}}{\frac{X_{ni}}{X_n}} = -\frac{\theta \delta_{ni}d}{(1 + \delta_{ni}d)} \left( 1 - \frac{X_{ni}}{X_n} \right).$$  (3)

Proposition 1: The trade elasticity of distance is always negative.
The proof of this proposition is straightforward as the term \(1 - \frac{X_n}{X_n}\) is bounded between 0 and 1, and the other term \(-\frac{\delta n_i d}{(1 + \delta n_i d)}\) is always negative for the range of possible values of the parameters.

Having defined the trade elasticity of distance in the context of the model, I can now determine how this elasticity is impacted by a change in transportation costs, measured by the parameter \(d\), or by a change in the production decentralization incentives, measured by the parameter \(\tau\).

The derivative of \(\varepsilon_{\delta n_i}\) with respect to transportation costs - \(d\) - is given by the following expression:

\[
\frac{\partial \varepsilon_{\delta n_i}}{\partial d} = -\frac{\theta \delta n_i}{(1 + \delta n_i d)^2} \left[ 1 - \frac{X_n}{X_n} \left( 1 - \frac{\theta \delta n_i d}{(1 + \delta n_i d)} \frac{\partial \Phi_n}{\partial \Phi_n} \right) \right]
\]

**Proposition 2:** The direction of the impact that a change in transportation costs has on the trade elasticity of distance is not well defined, it can either be negative, neutral or positive.

This result is quite surprising as the prevailing idea was that transportation costs and the elasticity of distance should be negatively related. The reason why this is not always true is that a change in transportation costs does not affect countries linearly and the impact is different for different countries.

The other result I am interested in is the impact of changes in production decentralization incentives and the elasticity of distance, which is given by the following expression:

\[
\frac{\partial \varepsilon_{\delta n_i}}{\partial \tau} = \frac{\theta \delta n_i d}{(1 + \delta n_i d)} \left( \frac{\partial \phi_{n_i}}{\partial \tau} \frac{\Phi_n}{\Phi_n^2} - \frac{\partial \phi_{n_i}}{\partial \tau} \frac{\Phi_n}{\Phi_n^2} \right)
\]

Where \(\phi_{n_i} = \tilde{T}_i (c_i (1 + \delta n_i d))^{-\theta}\).

**Proposition 3:** The direction of the impact that a change in the incentives of production decentralization has on the trade elasticity of distance is not well defined, it can either be negative, neutral or positive.

Like in the previous case it is not possible to determine the direction of the impact that changes in \(\tau\) have on \(\varepsilon_{\delta n_i}\). In this case though it is possible to take one step further and show that for some countries the impact will be positive while for other countries
it will be negative. This is so because the sign of expression (5) is solely determined by
the sign of \( \frac{\partial \delta_{ni}}{\partial \tau} \Phi_n - \frac{\partial \delta_n}{\partial \tau} \) and this expression can be re-written as follows:

\[
\left( \frac{\partial \tilde{\phi}_{ni} \tilde{\Phi}_n - \tilde{\phi}_{ni} \frac{\partial \tilde{\Phi}_n}{\partial \tau}}{\tilde{\phi}_{ni} \tilde{\Phi}_n} \right) = \frac{\left( \frac{\partial \delta_{ni}}{\partial \tau} \Phi_n - \frac{\partial \delta_n}{\partial \tau} \right)}{\tilde{\phi}_{ni} \tilde{\Phi}_n} \]

(6)

What this means is that if the impact of a change in \( \tau \) on the competitiveness\(^1\) of
country \( i \) is higher than the overall weighted average impact, then the distance elasticity
of trade becomes larger, otherwise it becomes smaller.

The results I have presented thus far regarding changes in production decentralization
assume that the change is symmetrical, but this does not have to be the case. In order to
see how the symmetry hypothesis affects the result I consider two cases: 1) only country
\( i \) increases \( \tau \); 2) only country \( j \neq i \) increases \( \tau \).

Case 1:

\[
\frac{\partial \epsilon_{\delta_{ni}}}{\partial \tau_i} = \frac{\theta \delta_{ni} d}{(1 + \delta_{ni} d)} \left( \frac{\partial \delta_{ni}}{\partial \tau_i} \sum_{j \neq i} \tilde{\phi}_{nj} \right) > 0.
\]

(7)

Case 2:

\[
\frac{\partial \epsilon_{\delta_{ni}}}{\partial \tau_j} = \frac{\theta \delta_{ni} d}{(1 + \delta_{ni} d)} \left( \frac{-\tilde{\phi}_{ni} \frac{\partial \delta_{nj}}{\partial \tau_j}}{\tilde{\phi}_{ni} \tilde{\Phi}_n} \right) < 0.
\]

(8)

**Proposition 4:** An asymmetric change in the incentives of production decentraliza-
tion will increase the trade elasticity of trade for the country that makes the change while
it reduces it for the countries that don’t respond.

This result is fairly intuitive and the proof of is given by equations (7) and (8). The
intuition is very simple, if country \( i \) increases the incentives for other countries to locate
production facilities in country \( i \) while the others do not respond, that will increase the

\(^1\)I am considering that \( \tilde{\phi}_{ni} \) measures the competiveness of country \( i \) when exporting to country \( n \).
overall and relative competitiveness of \( i \) and therefore country \( i \) will be able to export farther, implying a reduction in the elasticity of trade. The result regarding the other countries other than \( i \) is also intuitive as what happens to these countries is that their relative competitiveness gets worse when compared to country \( i \)'s and therefore they will face a smaller distance elasticity of trade.\(^2\)

Even though the previous results are interesting they are not very easy to validate (or reject) empirically nor give much insight about what to expect empirically. In order to get some more intuition I derived the results of propositions 2 and 3 for the case with only two countries.

**Proposition 2A:** In the case of only two countries, an increase (decrease) in transportation costs will decrease (increase) the distance elasticity of trade.

In the case of two countries, equation (5) simplifies to:

\[
\frac{\partial \varepsilon_{d_{ni}}}{\partial d} = -\frac{\left(1 - \frac{X_{ni}}{X_n}\right)}{(1 + \delta_{nd}d)^2} \left(1 + \theta \delta_{nd}d \frac{X_{ni}}{X_n}\right) < 0
\]

(9)

In this case, the sign of \( \frac{\partial \varepsilon_{d_{ni}}}{\partial d} \) is unequivocally negative, which is more in line to what is normally expected. The interpretation of the two results, propositions 2 and 2A, is not straightforward, but my personal interpretation is that although in general the sign of \( \frac{\partial \varepsilon_{d_{ni}}}{\partial d} \) is undetermined this indetermination is not very relevant from an empirical point of view.

**Proposition 3A:** In the case of only two countries, an increase (decrease) of the incentives to decentralize production leads to: 1) an increase (decrease) of the trade elasticity of distance if country \( i \) is less technologically developed than country \( n \); 2) a decrease (increase) of the trade elasticity of distance if country \( i \) is more technologically developed than country \( n \); 3) no impact on the trade elasticity of distance if the two countries are equally technologically developed.

To show this result I use the result of equation (6) and re-write for the case of only two countries:

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\(^2\)Notice that by higher and lower elasticity of distance I mean that the elasticity of distance become less or more negative, respectively.
\[
\left( \frac{\partial \phi_{ni} \Phi_{n} - \tilde{\phi}_{ni} \partial \Phi_{n}}{\partial \tau} \right) = \left( \frac{\partial \phi_{ni} \tilde{\phi}_{nn} - \tilde{\phi}_{ni} \partial \phi_{mn}}{\partial \tau} \right) = \left( \frac{T_{ii} - T_{nn}}{T_{ii} + rT_{nn}} \right) \frac{\tilde{\phi}_{ni} \tilde{\phi}_{mn}}{\phi_{mi} \phi_{mn}}
\]

Equation (10) is positive if \( T_{nn} > T_{ii} \), negative if \( T_{nn} < T_{ii} \) and 0 if \( T_{nn} = T_{ii} \). The implication of this result is that I can organize the data into high and low technology countries and test whether the elasticity of distance between the 4 groups (High-High, High-Low, Low-High and Low-Low) has the expected time variation.

### 3. EMPIRICAL ANALYSIS

In this section of the paper I describe the data that I used, I discuss various methodological alternatives and show some empirical results that support some of the findings of section 2.

#### 3.1. Data

The data that I used in this paper consists of bilateral export data that is aggregated to the country level. The data runs from 1970 to 2004 and for estimation and interpretation purposes I aggregated the data further into 5 year periods, that is, I added all exports between country \( i \) and country \( j \) for every five years. The other variables that I use are total real GDP, also aggregated for 5 year periods and other variables that are commonly used in the estimation of the gravity equation - distance between pairs of countries, indicator for common language, indicator for island, number of landlocked countries in the pair (0, 1 or 2), indicator for common water, land area of the country, indicator for current colonies, indicator if countries ever had a colonial relationship, indicator if the countries are/were the same country - and these were obtained from CEPII. Table 1 shows some summary statistics of the data.
### Table 1 - Data summary statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>Stdev.</th>
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<tbody>
<tr>
<td>Exports (million $US)</td>
<td>87.31</td>
<td>0.10</td>
<td>0</td>
<td>132464.5</td>
<td>1142.86</td>
</tr>
<tr>
<td>GDP (million $US)</td>
<td>$2.26 \times 10^8$</td>
<td>$3.01 \times 10^7$</td>
<td>$78669$</td>
<td>$1.01 \times 10^{10}$</td>
<td>$7.62 \times 10^8$</td>
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<tr>
<td>Distance (Km)</td>
<td>7715</td>
<td>7228</td>
<td>10</td>
<td>19904</td>
<td>4461</td>
</tr>
<tr>
<td>Common language</td>
<td>0.18</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.39</td>
</tr>
<tr>
<td># Island</td>
<td>0.37</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.55</td>
</tr>
<tr>
<td># Landlocked</td>
<td>0.32</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.52</td>
</tr>
<tr>
<td>Common water</td>
<td>0.11</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.32</td>
</tr>
<tr>
<td>Land area (Km²)</td>
<td>$5.84 \times 10^{11}$</td>
<td>$2.28 \times 10^{10}$</td>
<td>1235</td>
<td>$1.59 \times 10^{14}$</td>
<td>$3.87 \times 10^{12}$</td>
</tr>
<tr>
<td>Current colony</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.02</td>
</tr>
<tr>
<td>Colony</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.12</td>
</tr>
<tr>
<td>Common colonizer</td>
<td>0.11</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.32</td>
</tr>
<tr>
<td>Colony after 1945</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>Same country</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td># Observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>134189</td>
</tr>
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<td># countries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>180</td>
</tr>
</tbody>
</table>

#### 3.2. Methodology

As it is well know, the gravity equation relates exports from country $i$ to country $j$ to the distance between the two countries and the economic size of each one of them. Besides these three variables, distance between $i$ and $j$ and the GDP’s of $i$ and $j$, more recent versions of the equation also incorporate variables like common language, former colony, if any of the countries is an island or if any of them is landlocked, etc. The relationship between the various variables is summarized as follows:

$$X_{i,j,t} = Y_{i,t}^{\alpha_1} Y_{j,t}^{\alpha_2} D^{\beta_{ij}}_{i,j} g (X_{i,j,t}, \beta) + \varepsilon_{i,j,t}$$  \hspace{1cm} (11)

In this equation $Y_{i,t}$ and $Y_{j,t}$ refer to the GDP’s of countries’ $i$ and $j$ in period $t$, $D_{i,j}$ is the distance between the two countries and $X_{i,j,t}$ refers to the other variables. Even
though the estimation of this equation may seem quite straightforward, the truth is that it raise several issues that play an important role in the estimates that are obtained. Before entering into the specific results of this paper I would like to discuss the various estimation issues and based on that make a choice of the estimation being used.

1 - To log or not log

The traditional approach to estimating equation (11) is to log-linearize first and then simply use OLS as the resulting equation is linear in all the parameters. The problem with this approach is two-folded: the first problem is that it is necessary discard the observations for which $X_{i,j,t}$ was zero as the log function is only defined for strictly positive numbers, that is, all the situations of no trade would be excluded. Second problem has to do with Jensen’s inequality, that is, $E[\ln(f)] \neq \ln(E[f])$. Santos Silva and Tenreyro (2006) were one of the first to acknowledge these two problems simultaneously and their recommendation is that the estimation of (11) should be done with a non-linear estimation method to deal with both problems simultaneously. One possible estimator is the pseudo maximum likelihood (PML) estimator based on the Poisson regression. The disadvantages of this estimator are low precision and the fact that is fairly computer intensive.

2 - Zero trade

As I mentioned above some observations of bilateral trade are zero, and this creates a problem when one log-linearizes equation (11). One alternative to this problem is using a non-linear estimation method, as mentioned previously, and another alternative is to add a positive number to all observations $X_{i,j,t}$. For example, adding 1 to $X_{i,j,t}$ would solve the zeros problem and with that all observations would be used. The advantage of this option is that it makes the estimation process very fast, as it is based in OLS, but it does not solve the Jensen’s inequality problem that I mentioned previously.

3 - Structural interpretation of the gravity equation

Another issue relating to the estimation of gravity equations has to do with the structural interpretation of the parameters being estimated. Anderson and van Wincoop (2003) argued that some of the variables/specifications of the gravity equation were not justified by an economic model. Following this idea, these authors, derived a gravity
equation based on a model of international trade. Their main contribution is to divide the barriers to trade into three components: 1) country’s $i$ individual barriers to trade, 2) country’s $j$ individual barriers to trade and 3) the trade barriers that are specific to the pair of countries $(i, j)$. The trade barriers that are specific to the pair of countries would correspond to the distance, while for the other two types of barrier the authors suggested to use exporter and importer fixed effects. This approach has the advantage of having a sounder theoretical foundation but, at the same time, the results depend on the assumptions made. Another disadvantage of this approach is the fact that it is computationally intensive due to the amount of country dummy variables.

In order to assess how these different issues affect the estimation of the gravity equation I estimate equation (11) under 5 different alternatives: 1) log-linearize the model and disregard the zero trade observations; 2) log-linearize the model, disregard the zero trade observations and add exporter and importer fixed effects; 3) log-linearize the model but add 1 unit to all export values so that the zero trade observations are included; 4) log-linearize the model, add 1 unit to all export values so that the zero trade observations are included and include exporter and importer fixed effects; 5) estimate the model using the Poisson PML estimator, but do not add exporter and importer fixed effects.\(^3\) Table 1 show the results of the 5 different estimations for the distance parameters over time.

\(^3\)Initially I had considered a sixth combination, estimate the model using the Poisson PML estimator and include exporter and importer fixed effects, but this combination ended up being computationally unfeasible.
As Table 2 shows, the estimation method used plays a very important role in the results. In this case, the exclusion of the zero trade observations seems to be the most relevant of all three. Both the non-linear and the linear, including or not fixed effects, estimation methods yield very similar results. The fact is that, although the estimation procedure may explain why the parameter of distance has increased over time, the truth is that even controlling for zero trade observations and country specific trade barriers, the increasing pattern does not go away. Based on these results I decided to use the Poisson PML estimation method as it seems to be the most conservative of all the methods and at the same time it is the only method that is unbiased. The only caveat of using PML is that there is a loss of precision in the estimation.

### 3.3. Estimation results

In the previous section I discussed and illustrated how the method of estimation that is used can influence the results. I also showed that even after controlling for various issues the elasticity of distance still increases over time. In this section I will show that
the variation over time of this parameter depends on the group of exporting countries being considered, as well as on the importing countries. I will also show that changes in globalization can be positively and negatively correlated with changes in the elasticity of distance.

A major difficulty of this part is that the results of section 2 do not have very strong implications, and therefore it makes the empirical design much more challenging. One of the few testable implications comes from proposition 3A. The result of proposition 3A states that trade from highly technologically developed to lower technologically developed countries should be more impacted by distance as globalization increases and the opposite should be true for trade from less developed countries to more developed countries. Even though this is a very clear implication, there is still the difficulty of determining the ranking of countries based on their technological capabilities. The reason for that is the fact that when looking at a country’s exports/production it is not easy to determine how much of that production is based on the country’s own technology or based on other country’s technology that have invested there. My attempt to solve this issue is to consider that real GDP per capita and technological advancement of a country should be highly correlated. Based on this assumption, I split the data into 4 groups: 1) trade between countries that have a GDP per capita above the median - this is the High-to-High group; 2) trade between countries where the exporter has a level of GDP per capita above the median while the importer’s GDP per capita is below the median - this is the High-to-Low group; 3) trade between countries where the exporter has a level of GDP per capita below the median while the importer’s GDP per capita is above the median - this is the Low-to-High group; 1) trade between countries that have a GDP per capita below the median - this is the Low-to-Low group. For each one of the 4 groups I estimated equation (11) using the PML estimation method. Before presenting the estimation results I would like to show first some more information regarding these 4 groups.
Figure 1 shows that between 1970 and 2004, more than 75% of World trade was between high income countries, but after 1990 that hegemony was reduced as trade from low income countries to high income countries and between low income countries increased substantially. In Figure 2 I show the cumulative variation of exports for the 4 groups of countries.

As expected, given that the World economy has become more globalized, for all 4 groups there was a sharp increase in the total amount of exports. Nevertheless, the two groups where this growth was the highest were the Low-to-High and Low-to-Low
groups. Finally, and just before showing the estimation results I want to show what is happening to the average length of trade (weighted by exports) for these 4 groups.

**Figure 3 - Average trade distance**

Figure 3 shows that overall the average distance of trade has declined. What is interesting is that after 1990 for the HH and HL groups the average trade distance declined but for the LH and LL groups it increased. I now show the estimation results for the 4 groups.

<table>
<thead>
<tr>
<th></th>
<th>$H - H$</th>
<th>$H - L$</th>
<th>$L - H$</th>
<th>$L - L$</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_{1970-74}$</td>
<td>-0.632 (0.057)</td>
<td>-0.683 (0.072)</td>
<td>-0.703 (0.127)</td>
<td>-0.753 (0.074)</td>
<td>-0.650 (0.058)</td>
</tr>
<tr>
<td>$\theta_{1975-79}$</td>
<td>-0.638 (0.043)</td>
<td>-0.682 (0.073)</td>
<td>-0.662 (0.119)</td>
<td>-0.851 (0.084)</td>
<td>-0.647 (0.046)</td>
</tr>
<tr>
<td>$\theta_{1980-84}$</td>
<td>-0.618 (0.041)</td>
<td>-0.653 (0.082)</td>
<td>-0.555 (0.135)</td>
<td>-0.881 (0.081)</td>
<td>-0.636 (0.044)</td>
</tr>
<tr>
<td>$\theta_{1985-89}$</td>
<td>-0.685 (0.044)</td>
<td>-0.722 (0.111)</td>
<td>-0.654 (0.113)</td>
<td>-0.852 (0.079)</td>
<td>-0.717 (0.047)</td>
</tr>
<tr>
<td>$\theta_{1990-94}$</td>
<td>-0.726 (0.038)</td>
<td>-0.754 (0.109)</td>
<td>-0.650 (0.101)</td>
<td>-0.949 (0.077)</td>
<td>-0.761 (0.044)</td>
</tr>
<tr>
<td>$\theta_{1995-99}$</td>
<td>-0.726 (0.034)</td>
<td>-0.858 (0.087)</td>
<td>-0.589 (0.090)</td>
<td>-0.944 (0.075)</td>
<td>-0.758 (0.043)</td>
</tr>
<tr>
<td>$\theta_{2000-04}$</td>
<td>-0.767 (0.031)</td>
<td>-0.888 (0.081)</td>
<td>-0.528 (0.011)</td>
<td>-0.842 (0.084)</td>
<td>-0.789 (0.037)</td>
</tr>
<tr>
<td>#Obs</td>
<td>36454</td>
<td>32869</td>
<td>32929</td>
<td>31937</td>
<td>134189</td>
</tr>
<tr>
<td>Pseudo $- R^2$</td>
<td>0.870</td>
<td>0.839</td>
<td>0.830</td>
<td>0.665</td>
<td>0.862</td>
</tr>
</tbody>
</table>

Table 3 - Distance elasticity over time estimates by direction of trade
The results of Table 3 are very interesting and they correspond to what proposition 3A suggested, that is, the importance of distance increased for trade flows originated in technologically developed countries whereas it decreased for trade flows originated in non-technologically developed countries. The results of Table 3 are graphically displayed in Figure 4.

![Graphs showing distance elasticity over time estimates by direction of trade.]

It is important to mention that the results of Table 3 do not prove my claim, but they are favorable evidence of it. Ideally I would now be showing more results to corroborate my idea, but unfortunately and just like I mentioned previously it is very hard to obtain data that would help me achieving such task. To illustrate this I added the KOF globalization index (only the economic globalization sub-index) to my data and computed its mean for the countries that are in the high and low tech groups (groups 1 and 2 and groups 3 and 4) over time. These are the results:
Fig. 5 - KOF globalization index over time by technological capabilities.

Not surprisingly, globalization has increased for both groups of countries. Nevertheless, the importance of distance for trade for these two groups of countries had different trajectories. To strengthen my point I estimated equation (11) separately for the high and the low tech countries. Based on the results that I obtained for these 2 groups of countries I computed the correlation between the coefficients of distance and the KOF globalization index. For the high tech countries I estimated that the correlation between the coefficient of distance and the KOF index is −0.92, while for the low tech countries the same correlation was 0.75. Figure 6 shows the results.

Fig. 6 - Relationship between globalization and the coefficient of distance for different groups of countries
As my results of section 2 indicated, the impact that globalization had on the elasticity of distance is different for different countries. While for more developed countries distance became more costly, due to more alternatives, for less developed countries distance became less costly.

4. CONCLUDING REMARKS

In this paper I re-evaluated one of the most puzzling results in international economics, the persistent effect of distance on trade. Based on a well known model of trade, Eaton and Kortum (2002), and on an extension of the same model, Dias and Richmond (2009), I showed that globalization does not necessarily lead to a decrease of the effect of distance on trade. My results suggest that even in the case when only transportation costs change, the elasticity of distance does not necessarily increase for all countries, it can actually decrease for some countries, and therefore the net effect is not well defined. Besides analyzing the impact that changes in transportation costs have on the distance elasticity of trade, I introduced the idea that globalization should not be seen just as a reduction in transportation costs, but it should also include changes in the costs of production decentralization. When production decentralization costs are reduced, firms have more incentives to have production in more than one place, which implies that the geography of trade is changed in non-trivial ways. Under this scenario, firms can now choose between producing centrally and shipping products or having multiple production facilities and with that minimize the transportation costs and/or the competition of other firms. This change will make distance more costly for some countries, the ones that do FDI, and less costly for other, the ones that receive FDI.

Using bilateral trade data to estimate the gravity equation I showed how the time pattern of the distance parameter in the gravity model could be decreasing, increasing or fairly flat. What this result tells us is the following: 1) globalization is a complex process for which most traditional trade models are not prepared for and consequently, trade policy is not being chosen optimally; 2) the usefulness of the gravity equation is
not questioned but the interpretation of the parameters must be done very carefully as these are not structural parameters but instead combinations of structural parameters.

As a follow-up of this paper I plan to investigate the central idea of this paper further by using US export data at the product level and information on stocks of FDI that the US owns abroad by type of product and by region. What I would like to show is that products for which the US has had a higher increase of FDI are products for which distance became more important. Also that regions where the US had the largest increase in FDI correspond to regions with smaller increase of US exports.

REFERENCES


