The distance puzzle revisited: a new interpretation based on geographic neutrality*

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Abstract

One of the most remarkable features of globalization is the boost underwent by international trade triggered off by advances in technology that have contributed to reduce the cost of trade (e.g., transportation and communication costs). Under these circumstances, the importance of distance should have diminished over time, which would constitute a boon for countries located far from the main centers of economic activity. However, one of the best-established empirical results in international economics is that bilateral trade decreases with distance. This apparent contradiction has been labeled as the "missing globalization puzzle". We propose yet another explanation to this apparent contradiction based on the concept of geographic neutrality, which we use to construct international trade integration indicators for two different scenarios, namely, when distance matters and when it does not. Our results indicate that the importance of distance varies greatly across countries, as revealed by disparate gaps between distance-corrected and distance-uncorrected trade integration indicators for different countries. Some factors rooted in the literature explain the discrepancies, but their importance varies according to the trade integration indicator considered—trade openness or trade connection.

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1. Introduction

The gravity model of bilateral trade is of primary importance in empirical analyses of trade patterns. Its simplest version states that trade interactions between two geographically defined economic entities (either countries or regions) are proportional to the size of these entities and inversely related to the distance between them (Combes, 2008). Not only has the model been utilized to further understand the underpinnings of trade flows in general but also to assess the role of their particular determinants such as distance, borders, currency unions, WTO membership, insecurity, institutions, etc. (Henderson and Millimet, 2008). According to these models, proximity is the main engine of trade between spatially distinct economic entities and, although this could *a priori* appear as an obsolete view of the world if one believes in the "death of distance" or the emergence of the "global village" (McLuhan and Fiore, 1968), there is a widespread reliance on the gravity model based both on its solid theoretical foundation, derived from several underlying theories (see, for instance, Anderson, 1979; Deardorff, 1998; Evenett and Keller, 2002) and the fact that it has proven empirically successful—explaining much of the variation in trade volume over time and space. In their meta-analysis study, Disdier and Head (2008) found that halving distance increased trade by 45%, and more recent analysis by these authors suggest that the distance effect has actually increased in more recent years.

Based on these ideas, some authors such as Leamer and Levinsohn (1995) state that the gravity model provides "some of the clearest and most robust empirical findings in economics" (Leamer and Levinsohn, 1995, p.1384), whereas others such as Rose (2000) note that the gravity model provides a "framework with a long track record of success" (Rose, 2000, p.11). Anderson and van Wincoop (2003) concur: "The gravity equation is one of the most empirically successful in economics" (Anderson and van Wincoop, 2003, p.170). This successful performance of the gravity model for explaining bilateral flows has been recently boosted by the availability of a growing number of "natural experiments" in the form of regional trade agreements (Greenaway and Milner, 2002).

As recognized by the literature on international trade, the standard gravity models that are usually estimated in the log-linear form are unable to capture the significant decline in trade costs brought by globalization of the world economy. These ideas were initially noted by Leamer and Levinsohn (1995), who stated that "the effect of distance on trade patterns is not diminishing over time. Contrary to popular impression, the world is not getting dramatically smaller". Some authors refer to this as the "missing globalization puzzle" (Coe *et al.*, 2002, 2007). Other recent proposals refer to it as "the conservation of distance in international trade" (Berthelon and Freund, 2008), "the puzzling persistence of the distance effect on bilateral trade" (Disdier and Head, 2008), or the question is even more strongly posed when asking whether "has distance died?" (Brun *et al.*, 2005), or when stating that "it is alive and well" (Carrere and Schiff, 2005). The number of studies on the issue is substantial, and the meta-analysis by Disdier and Head (2008) provides a useful summary, concluding that the estimated negative impact of distance on trade rose around the middle of the twentieth century, has remained persistently high since then, and such a result holds even after controlling for the heterogeneity in samples and methods across studies.

In this paper we suggest yet another solution to the "missing globalization puzzle" in the gravity equation. We build on Arribas *et al.* (2009), who construct indices of international trade integration taking into account some relevant yet somehow "forgotten" ideas by the international economics literature, namely, the Standard of Perfect International Integration devised by Frankel (2000), and the concept of geographic neutrality coined by Krugman (1996). Considering also some ideas derived from network analysis theory, whose relevance for trade has been recently revealed by Kali and Reyes (2007), Arribas *et al.* (2009) construct an indicator of international trade integration decomposable in two components aimed at measuring both how open and connected economies are.

Our solution to the missing globalization puzzle is based on a modified version of Arribas *et al.*'s indicators of integration. Motivated by the robust empirical regularity that bilateral trade flows between pairs of countries are explained well by the product of their gross domestic products (GDPs) and, very importantly, their bilateral distance, we include the latter when building our measures of trade integration. Specifically, we construct indicators in which both inter-country and intra-country distances are taken into account, since both are relevant for countries' imports and exports as documented not only by the literature on gravity equations (in the case of inter-country distances) but also by Alesina and Spolaore (1997) (in the case of intra-country distances). The comparison of both sets of indices (distance-corrected and distance-uncorrected) enables carrying out a new assessment of the role of distance for determining international trade flows.

The rest of the article is structured as follows. Section 2 presents the methodological contents of our approach to measure international economic integration. Sections 3 and 4 present the data set and empirical application, respectively, by considering data on exports of goods for a wide set of countries that account for most of world output and trade, and for a relatively long sample period (1967–2005). Section 5 explores the determinants of the discrepancies between the original and distance-corrected indicators. Finally, Section 6 concludes.

2. Defining distance-corrected integration indicators

The first indicator of international trade integration we consider is openness of economies, but we also judge relevant to include the structure of the current trade relations between them—or what some authors have labeled the "architecture" of trade flows (Kali and Reyes, 2007). Relevant aspects of this architecture include the number of trade partners, the proportionality of trade flows to the size of the partners[1] and the role of barriers—particulary distance.

In order to characterize a benchmark of trade integration, we define an extension of concept of geographic neutrality Kunimoto (1977); Krugman (1996); Iapadre (2006) closely related with the Standard of Perfect International Integration (SPII) in Arribas *et al.* (2009): the flow from one economy to another depends only on their relative sizes aquí habría que incluir algo de lo que he encontrado de Kunimoto. Our notion of integration shares with the SPII that it also verifies the properties of domestic neutrality, direct international neutrality and size, but differs in the consideration of the distance as a key factor. More precisely, our definition of SPII also integrates the Samuelson's (1954) standard iceberg assumptions,

[1] This approach has several links with the literature on social networks. See, for instance, Annen (2003), Hanneman and Riddle (2005), Karlin and Taylor (1975), Wasserman and Faust (1992), or Wellman and Berkovitz (1988).

thus we consider that the flow between to economies not only is proportional to their relative size but also depends inversely on the distance between the economies. In short, under our neutrality assumption the following properties must be verified:[2]

Domestic neutrality: An economy whose domestic demand is proportional to its share of the world economy will have a higher level of integration.

Direct international neutrality: An economy that balances its direct relations with other individual economy, in proportion to their sizes and inversely to their distances will have a higher level of integration.

In order to discover the extent to which economies meet the two properties mentioned above, we must define an integration index and assess the distance that separates the current level of integration from the SPII. We will proceed in three stages, each one defining different indicators.

2.1. Notation

Let us start with some definitions. Let N be the set of economies and let i and j be typical members of this set. Even when the following definitions should be indexed by the year, to clarify notation we will omit that index. Let Y_i be the size of economy $i \in N$, for example its GDP and let d_{ij} be the geographic distance between the economies i and j, where d_{ii} means the economy i's internal distance.

In order to compare economies that are not contiguous, we follow Samuelson's standard "iceberg" assumption considering that if a economy j of size Y_j is carried as close to economy i as possible, then its size will reduce to Y_j/d_{ij}^{θ} (i.e., as stated by Samuelson (1954), "only a fraction of ice exported reaches its destination as unmelted ice"), where θ is a non-negative parameter which measures de impact of distance (the farther the economies are, the greater the reduction is, with an intensity that depends on the θ parameter). In the extreme case in which $\theta = 0$ the "iceberg" effect disappears.

We define r_i as the economy i's relative weight with respect to a world economy where the correction through distance has been done (distance corrected world) i.e., $r_i = (Y_i/d_{ii}^{\theta})/\sum_{j\in N}(Y_j/d_{ij}^{\theta})$. Notice that: i) we also consider that there exists an iceberg effect on the home economy, (due to countries' differing geographic sizes) or, equivalently, that transportation cost exists both for inter- and intra-national trade; ii) the above definition does not depend on the units of measurement for the distance between economies given that r_i can be write as $r_i = Y_i/\sum_{j\in N}(Y_j/(d_{ij}/d_{ii})^{\theta})$. This expression enables re-interpreting the effect of the geographic distance as the one given by a normalized distance matrix between economies where every internal distance of the economies is 1 and the distance from economy i to economy j is d_{ij}/d_{ii}, the times the geographic distance between these economies is bigger than the economy i's internal distance; and iii) the impact of the distance depends on the θ parameter. In a world where the distance is irrelevant, $\theta = 0$ (geographic neutrality).

Given a measurable relationship between economies, we define the flow X_{ij} as the intensity of this relationship from economy i to economy j. The flow between economies can be evaluated through either the imports or the exports of goods, capital, or any other flow measured in the same units as Y_i. Moreover, in general the flow will be asymmetric, so that X_{ij} will not necessarily be equal to X_{ji}, for all $i, j \in N$. We also assume that $X_{ii} = 0$ for all economy $i \in N$. All definitions in this paper depends on the flow

[2] See Arribas *et al.* (2009) for further details

considered to measure the international integration.

2.2. Definitions

Next definitions are based on the ones in Arribas *et al.* (2009) but considering the distance between economies. In this section we give the mathematical definitions and we reference the readers to the paper by Arribas *et al.* (2009) for further details.

Degree of Openness

First we characterize the *degree of openness* assuming that the orientation of production towards domestic demand is not biased. In order to remove the domestic bias we define $\widehat{Y}_i$ as the flow from economy i to the world taking into account the weight in the distance-corrected world economy of the economy under analysis, namely, $\widehat{Y}_i = Y_i - r_i Y_i$. Then, we define the relative flow or **degree of openness** between economies i and j as $DO_{ij} = X_{ij}/\widehat{Y}_i$. Given that $X_{ii} = 0$, it follows that $DO_{ii} = 0$ for all $i \in N$.

Definition 1 *Given an economy $i \in N$, we define its **degree of openness**, DO_i, as*

$$DO_i = \sum_{j \in N} DO_{ij} = \frac{\sum_{j \in N} X_{ij}}{\widehat{Y}_i}. \tag{1}$$

We write DO instead of DO_i when general statements on the degree of openness are being made, or references to the variable itself, which do not hang on any specific economy. The same rule will be applied to the other indicators.

Degree of Balanced Connection

Second stage we analyze whether the connection of one economy with others is proportional to their sizes in terms of GDP,[3] or whether this connection does not show geographical neutrality, Thus, we define the *degree of balanced connection* to measure the discrepancy between the trade volumes in the real world and those trade volumes corresponding to the SPII.

In the economic network, the relative flow from economy i to economy j in terms of the total flow of economy i, α_{ij}, is given by

$$\alpha_{ij} = \frac{X_{ij}}{\sum_{j \in N} X_{ij}} \tag{2}$$

(recall that we are assuming $X_{ii} = 0$). Let $A = (\alpha_{ij})$ be the square matrix of relative flows: the component ij of matrix A is α_{ij}.

We consider that the distance-corrected world world economy is perfectly connected if the flow between two economies is proportional to their relative sizes. Thus, if the world economy is perfectly connected, then the flow from economy i to economy j should be equal to $\beta_{ij}\widehat{Y}_i$, where

$$\beta_{ij} = \frac{Y_j/d_{ij}^{\theta}}{\sum_{k \in N \setminus i}(Y_k/d_{ik}^{\theta})} \tag{3}$$

is the relative weight of economy j in a distance-corrected world where economy i is not considered.

[3]The dependence of both the number and magnitude of exchanges on economy size is the focus of international trade analyses based on gravity models and widely used in the literature (Hummels and Levinsohn, 1995; Feenstra *et al.*, 1998, 2001; Rauch, 1999).

Note that $\sum_{j \in N \setminus i} \beta_{ij} = 1$ and that β_{ij} is the degree of openness between economies i and j in the perfectly connected world, with $\beta_{ii} = 0$. Let $B = (\beta_{ij})$ be the square matrix of degrees of openness in the perfectly connected world.

Definition 2 *Given an economy $i \in N$ we define the* ***degree of balance connection*** *of i, DBC_i, as*

$$DBC_i = \frac{\sum_{j \in N} \alpha_{ij} \beta_{ij}}{\sqrt{\sum_{j \in N} (\alpha_{ij})^2} \sqrt{\sum_{j \in N} (\beta_{ij})^2}}. \tag{4}$$

Degree of Integration

From the above two concepts, we define the *degree of integration*, which combines degrees of openness and balanced connection, and for both of them we set limits to the integration level achieved:

Definition 3 *Given an economy $i \in N$ we define its* ***degree of integration****, DI_i, as*

$$DI_i = \sqrt{\min\{DO_i, 1/DO_i\} \cdot DDC_i} \tag{5}$$

Therefore, our indicators consider the two main regressors included in any gravity equation, i.e., the size of the trading economies, and the distance between them. One of their advantages is that, instead of providing us with information as to whether these variables are important for trade flows, it will be possible to measure the gap from the scenario of complete trade integration in goods under different hypotheses on the impact of distance (on the "iceberg" effect).

3. Data presentation

We consider the international economic integration indicators defined above to study the evolution of international trade. Some slight modifications on the indices would enable analyzing also international financial integration. Our application is restricted to trade flows only, for which it is required information on the volume of activity (GDP) for each country together with their trade flows with the rest of the world.

Data on bilateral trade flows from the `CHELEM` data set[4] corresponding to 59 countries accounting for 96.7% of world output and 86.5% of international trade. The variable selected to measure flows between countries is the volume of exports.[5]

The available information covers a relatively long period of time, from 1967 to 2005, uncovering entirely what some authors have termed the second wave of globalization (O'Rourke and Williamson, 1999, 2002; Maddison, 2001). The data set also contained information for other countries, yet it was not available for all sample years, thus we disregarded it.

The same institution providing data on trade flows and GDP (CEPII, Paris) also provides other relevant pieces of required information such as distance. Two types of distances are considered. The distance from country i to country j (external distance, d_{ij}) is measured by the distance between the main city of the

[4]Information on `CHELEM` (*Comptes Harmonisés sur les Echanges et l'Economie Mondiale*, or Harmonised Accounts on Trade and The World Economy) database is available at `URL http://www.cepii.fr/anglaisgraph/bdd/chelem.htm`. Data compiled by CEPII, Paris.

[5]The computations for indicators based on imports do not alter the general results, although they may differ for some specific countries. These results are not reported due to space limitations, but are available from the authors upon request.

country which, in most cases, is the capital of the country. The data set also provides data for *internal* distances (d_{ii}), as also required by our indices. See Head and Mayer (2002) for details.[6]

Our analysis is restricted to trade in goods. Since specialization patterns vary across countries, there is a bias for our indices which will affect countries differently. However, extending the analysis to account for trade in services is not possible, since there is no services equivalent to the matrix of trade in goods between country pairs.

4. Results

4.1. Degree of openness, degree of balanced connection and degree of integration

As Figure 1 indicates, on average, the degree of openness has more than doubled (for $\theta = 0$) and almost tripled (for $\theta = 1$) from 1967 to 2005. Comparing $DO_i^{\theta=0}$ to $DO_i^{\theta=1}$, accounting for distance makes the degree of openness increase from 32.09% to 40.71% (year 2005). The upper panels in Figure 1 show the evolution of $DO^{\theta=0}$ and $DO^{\theta=1}$ summary statistics (mean, weighted mean, and median). In all cases there is a sharp increase, although the effect is dimmed for the larger countries, especially under geographic neutrality.

Results for the degree of global openness (DGO) correspond to the evolution of the weighted mean in both upper panels. They are also reported in Table 1, given our special interest in finding integration indicators. It would suggest *how open* the world economy is, and it is apparent that if we recognize that distance matters, the level of openness is higher. In both instances, however, the degree of openness advances at a similar pace: in the economy where distance is irrelevant ($\theta = 0$), the increase is from 8.03% to 20.84%, and in case location mattered ($\theta = 1$), the increase is higher (from 12.13% to 32.27%). However, the analysis by subperiods discloses additional results: under $\theta = 0$, the highest increase took place after 1986, whereas for $\theta = 1$ it occurred before. This finding may be explained by the role of countries such as Japan, which is big in GDP terms (therefore its behavior affects the evolution of DGO), which is distant, and whose $DO_i^{\theta=0}$ increased sharply before 1986.

The middle graphs in Figure 1 displays results for the degree of balanced connection ($DBC_i^{\theta=0,1}$). The most apparent feature is that they are much closer to the economies' theoretical full potential (100%) than the DO, particularly when distance matters ($\theta = 1$). However, the average increases have been more modest than in the degree of openness case, also because initial levels were already high. These tendencies are common under geographic neutrality and $\theta = 1$, although the increase has been even more modest in this last case. The values corresponding to the degree of global balanced connection $DGBC$ are also reported in Table 1. In contrast to the result obtained for the degree of openness, the wealthier countries are those with highest degrees of balanced connection. These values peaked before the 1990s. The most interesting results, however, emerge when dropping the physical irrelevance assumption and distance enters the analysis, since now all countries lie above $DBC = 70\%$. Therefore, once the downward impact of distance on the volume of trade is controlled for, countries export more "proportionally" to the size of their trading partners. In other words, if as found and predicted by gravity models distance matters, and

[6]See also `www.cepii.fr/anglaisgraph/bdd/distances.htm`.

its importance does not seem to diminish strongly over time despite the decline in transportation costs, the current level of balanced connections would already be high. However, the balance would be lessened from the perspective of a global village, where the role of remoteness disappears.

The degree of integration results from combining the effects of the DO and the DBC. The evolution of the basic summary statistics is reported in the lower panel of Figure 1. The relevant message is not only that it indicates the level of international trade integration achieved on average by each country but, more importantly, that it indicates how far each country is from its theoretical full potential for integration. In general, countries are more integrated when controlling for distance, although there are some exceptions to this rule, whose degrees of integration decrease. The interpretation for these particular cases is straightforward: these are countries whose export flows suffer from a "distance bias", the major trading partners for these countries are remotely located—i.e., in the case of distance being relevant, they should export more to their geographic neighbors. Therefore, it is obvious that this type of result only arises for countries sharing several characteristics, among which we might consider the fact of being surrounded by developing countries (e.g., Algeria, Gabon, Nigeria, Pakistan and, to a lesser extent, Chile) or being highly exporting countries whose trading partners are physically distant (China, Malaysia and Singapore). The specific values for the degree of global integration (DGI) are reported in Table 1. The general assessment of the level of world integration (DGI) as of 2005 is that, in the case of distance still being relevant, we are already halfway to the theoretical full potential for global trade integration. However, from the "global village" perspective in which distance becomes an irrelevancy, the process is still in a previous stage, since the degree of global integration decreases sharply (from 50.96% to 35.48%). However, the variety of behaviors is wide: the standard deviation (not reported) has increased sharply (although the coefficient of variation has declined due to the growing average), and probability mass becomes increasingly spread, suggesting that some countries are quite close to the unity, yet many others are still far—although the prevailing picture is that trade integration is advancing.

5. Analyzing the determinants of the distance trade bias

Figure 2 provides a preliminary view on how the role of distance has evolved over the 1967–2005 period. It shows the evolution of the $DGO^{\theta=1}/DGO^{\theta=0}$, $DGBC^{\theta=1}/DGBC^{\theta=0}$ and $DGI^{\theta=1}/DGI^{\theta=0}$ ratios, which has been rather disparate. Whereas all three indicators departed from similar values (ranging in the $]1.4, 1.6[$ interval), the $DGO^{\theta=1}/DGO^{\theta=0}$ increased until the mid nineties, and then decreased to virtually the initial value. The evolution of the $DGBC^{\theta=1}/DGBC^{\theta=0}$ has been opposite, but much more attenuated. $DGI^{\theta=1}/DGI^{\theta=0}$ shows their combined effect.

We consider that large discrepancies among distance-corrected and non-corrected values of our trade integration indicators constitute an equivalent to the persistence of the distance coefficient in gravity equations. The basic version of these models considers that trade between country i and a number of partner countries j, T_{ij}, is a function of GDP of both country i, Y_i, and country j, Y_j, and geographic distance between the two countries, , $DIST_{ij}$. Therefore, the following model and the like are generally estimated,

$$\ln T_{ij} = \beta_0 + \beta_1 \ln(DIST_{ij}) + \beta_2 \ln(Y_i) + \beta_3 \ln(Y_j) + \varepsilon_{ij} \tag{6}$$

where ε_{ij} is the error term. The r.h.s. of Equation (6) is usually enlarged so as to control for common language, common land border, a common colonizer, the condition of being landlocked, the existence of a free trade area, and sometimes a common currency.

As we have documented, discrepancies among distance-corrected and non-corrected trade integration indicators vary a great deal both on average and, most importantly, across countries. This implies that the effect of distance *is not homogeneous* across countries and, therefore, the estimated β_1's in Equation (6) might be country-dependent. This would imply that when tackling the issue of whether "distance has died" or not, we should temper the statements by adding that distance is still significant *on average*. Some authors have indeed pointed out that nonlinearity may be the problem. For instance, Coe *et al.* (2007) estimate a gravity equation with an additive error term and find that there was some decline in the distance coefficient.

We explore now some covariates which could contribute to explain the different role of distance for different countries. Some of them are variables capturing the existence of regional trade agreements. Although there is a wide range of different forms of integration arrangements, including free trade areas, customs unions, and preferential trading areas, we use RTAs as a generic descriptor (Greenaway and Milner, 2002). Some authors consider regionalism might enhance short-distance trade and therefore be the most obvious explanation for the non-declining role of distance (Berthelon and Freund, 2008), whereas technological improvements might favor long-distance trade. Indeed, some authors such as Hummels (1999) find that containerization reduced the relative cost of distance. As indicated by Alesina and Spolaore (1997), trade blocs (which they label as political integration) harm economic integration, which is the reason why economic integration is usually found to be low in countries who have signed free trade agreements.

Although there are currently more, we consider only the most important RTAs, namely, the European Union, NAFTA, MERCOSUR and ASEAN. These are major RTAs in Europe, North America and Asia, although a relatively small but growing number apply to the trade of developing countries. Most applications of the gravity model have also searched for evidence of actual or potential effects by adding dummy variables for membership of a particular RTA. We add a related variable whose importance is not always considered by the literature, namely, the number of years each country has been member of its corresponding RTA. By including this dummy variable, we will be able to test whether there is an identifiable RTA effect, and to recognize those variables on which the RTAs' dummies may have the stronger effects. In addition, it constitutes a good proxy for the depth of the commercial links between the different trading partners.

We also include in our regressions the GDP of each country—recall that since we have constructed country-specific indicators we do not use bilateral information. Gravity equations find generally that the economic size of each partner is a significant explanatory variable for the trade volumes between them. In our specific setting, the equivalent result would be that country i's GDP is significant. Not only has the literature on gravity equations documented this issue but also Alesina and Spolaore (1997, 2003) among others, who argue that bigger domestic markets constitute important incentives for large countries to trade less. As also indicated by Brun *et al.* (2005), trade tends to constitute a smaller percentage of GDP for larger countries.

We include in our regressions some of each country's specialization patterns. There is a vast literature on the effects of specialization on trade. The changing composition of trade has been found to be an explanation for the stability over time of the estimated distance coefficients in gravity equations (Coe *et al.*, 2002). As indicated by Berthelon and Freund (2008), the increase in the importance of distance, estimated using aggregate gravity regressions could be due to an increase in the share of trade accounted by distance-sensitive products. Indeed, these authors find that distance has become more important for *some* industries. Thus, this information is crucial for explaining whether the effect of distance is still there or not, since there are some products which will be traded very much regardless of where trading partners are located. This type of products may be especially oil or raw materials. In addition, in many cases the countries surrounding the main producers of these products have similar specializations, which makes the role of distance even more severe. In order to control for these issues, our model includes both the shares of total energy and refined petroleum in each country's GDP.

Therefore, we estimate three basic models, since we consider the impact of the selected covariates in our three main indicators (openness, connection, integration). If we refer to the ratio $D^{\theta=1}/D^{\theta=0}$ as the general expression for the three ratios $DO^{\theta=1}/DO^{\theta=0}$, $DBC^{\theta=1}/DBC^{\theta=0}$ and $DI^{\theta=1}/DI^{\theta=0}$, then the model to be estimated presents the following general form:

$$D_{it}^{\theta=1}/D_{it}^{\theta=0} = \alpha_i + \beta_1 GDP_{it} + \beta_2 ENERGY_{it} + \beta_3 REFINED_{it} + \beta_4 YRTA_{it} + \beta_5 RTA_{it} + \varepsilon_{it} \qquad (7)$$

where GDP_{it} is the logarithm of country i GDP in year t, $ENERGY_{it}$ and $REFINED_{it}$ are the shares of total energy and refined petroleum in country i GDP in t, respectively, $YRTA_{it}$ are the numbers of years country i is member of its corresponding RTA (if this applies) in year t, and RTA_{it} is a dummy variable which takes the value of 1 for countries members of the RTA considered. We include the t subscript to account for the time dimension of the role of distance. As indicated by Brun *et al.* (2005), if using cross-section to estimate Equation (7) and the like, there are potential problems. Some of them are related to the heterogeneity not captured by dummy variables, which could cause bias estimates. Others are related to the omitted-variables bias to which typical ordinary least squares estimates may be prone to. Therefore, we estimate Equation (7) using cross-section fixed effects, which are included in the α_i parameter, so that the unobservable heterogeneity is partly addressed.

However, the impact of the different RTAs on distance might be involved, since RTAs differ in many respects. For instance, in Europe integration goes beyond merely establishing a free trade area, since both capital and labor can move freely and there is an even more ambitious initiative for political integration with the European Constitution. This is a big contrast with the features of NAFTA, where free flow of labor across member estates is not possible. Therefore, we consider relevant to analyze how each particular RTA might affect distance by considering four simpler versions of Equation (7) in which the RTA variable is substituted by EU, $NAFTA$, $ASEAN$ and $MERCOSUR$ variables.

Table 2 shows estimation results for Equation (7) in which the dependent variable is $DO^{\theta=1}/DO^{\theta=0}$, whereas Table 3 and Table 4 show the same information for $DBC^{\theta=1}/DBC^{\theta=0}$ and $DI^{\theta=1}/DI^{\theta=0}$, respectively. As indicated Table 2, the effect of GDP on distance—as measured by larger discrepancies among $DO^{\theta=1}$ and $DO^{\theta=0}$—is positive. This implies that for big economies openness is strongly affected by distance, as heavily documented in the literature. This coefficient is positive and significant at the 1% significant level throughout.

In contrast, the share of total energy in each country's exports ($ENERGY$) affects negatively and significantly throughout the discrepancies between $DO^{\theta=1}$ and $DO^{\theta=0}$. This result is reasonable, implying that high energy-exporting countries are those whose openness is less affected by distance (their volume of exports is not determined by the location of their trading partners), whereas the opposite pattern holds for low energy-exporting countries. The effect is the opposite for $REFINED$, which is also expectable because most developed countries are able to refine their oil imports and, therefore, the trade volumes of this good will be mostly determined by distance.

The variables related to free trade areas must be commented on jointly, given there are non-negligible interactions among them. Those countries for which the $DO^{\theta=1}/DO^{\theta=0}$ ratio is larger are those which are strongly affected by distance when evaluating their degrees of openness. However, as indicated by the last column in Table 2 (corresponding to Model 5), being member of a regional trade agreement (RTA variable) affects negatively $DO^{\theta=1}/DO^{\theta=0}$. Therefore, countries adhered to RTAs are less affected by distance in their degrees of openness or, equivalently, they do not necessarily trade more with their neighbors—which are usually also their trading partners. However, not all RTAs contribute in the same way, since both EU and $MERCOSUR$ corroborate the negative sign found for RTA (especially in the case of $MERCOSUR$), whereas both $NAFTA$ and $ASEAN$ are virtually non-significant. Therefore, one may easily infer it is relevant to consider the different trade agreements separately due to their varying effects on the dependent variable. Finally, we also analyze the "depth" of the free trade agreements, as measured by $YRTA$, whose sign is negative and significant (1%) throughout, i.e., the longer the duration of the RTA, the less relevant the effect of distance—as revealed by lower discrepancies between $DO^{\theta=1}$ and $DO^{\theta=0}$. Therefore, it seems that once a particular country becomes member of a RTA, the effect of distance shortly turns as relevant as for older members.

We now turn to the analysis of the impact of each covariate on $DBC^{\theta=1}/DBC^{\theta=0}$. In general, as revealed by Table 3, the results vary remarkably with respect to those in Table 2, constituting further evidence on how different the economic meanings of the degree of openness and the degree of direct connection are. Indeed, in many instances the sign of the relationships is reversed, corroborating that DO and DBC are but different ways through which economies become more trade integrated.

The impact of GDP on $DBC^{\theta=1}/DBC^{\theta=0}$ is negative and significant throughout. Countries for which this discrepancy is high are those whose trading partners (both in terms of number and *proportionality*) are close—i.e., once we control for distance, the DBC increases sharply. However, this effect is stronger for poorer countries, which are more "connected" to their neighbors, as revealed by the negative sign. The specialization variables—$ENERGY$ and $REFINED$—are not entirely coincidental either. Although the sign and significance for $REFINED$ coincides, latter $ENERGY$ loses its significance throughout.

The variables related to free trade area membership do also show dissimilar patterns when comparing the results in Table 3 to those in Table 2. The general effect (RTA) is not only reversed (its sign is now), but in addition it loses significance entirely. However, this outcome is the combined effect of opposed effects. On the one hand, analogously to what was found for DO (Table 2), the effect of $ASEAN$ is negative and significant. On the other hand, all EU, $MERCOSUR$ and $NAFTA$ not only are significant but, most importantly, the sign is positive. Again, the effect of free trade area membership varies across the different trade agreements. In the particular case of EU, $MERCOSUR$ and $NAFTA$ the positive effect indicates that the architecture of trade relations of their members is positively biased towards other members of the agreement. In the case of $ASEAN$ the effect is the opposite, the bias exists towards non-members of the free trade agreement.

Table 4 shows the effect on $DI^{\theta=1}/DI^{\theta=0}$ of the different explanatory variables. Since the dependent variable is constructed as a square root of the product of DO and DBC, the results in Table 4 are those one might expect by combining results in Table 2 and Table 3. However, since the degree of openness and the degree of connection convey different economic meanings, results in Table 4 are involved, consisting basically of a dominance effect—i.e., the sign of the relationship is originated by the effect that actually dominates the relationship.

In those cases in which the effects were opposite, the significance is lost. That is the case of GDP, whose impact on $DI^{\theta=1}/DI^{\theta=0}$ is positive, albeit non-significant—as a result of a positive and significant effect on $DO^{\theta=1}/DO^{\theta=0}$ and a negative and significant effect on $DBC^{\theta=1}/DBC^{\theta=0}$. In the case of $ENERGY$, its negative and strongly significant effect on the degree of openness dominates, resulting into a negative and significant effect on the degree of integration for all models—although for models 3-5 significance decreases to 10% only. However, there were other cases such as $REFINED$ and $YRTA$ in which both the sign of the relationship and the significance coincided and, therefore, the impact on the degree of integration is maintained.

The impact of the free trade area variables is more involved. In general, the sign of the relationship coincides with the sign and significance found for the degree of connection (Table 3), with the exception of RTA for which significance is lost. Therefore, it seems for these variables (EU, $NAFTA$, $ASEAN$, $MERCOSUR$ and the summary variable, RTA), the importance of the degree of openness is dimmed with respect to the degree of connection.

6. Conclusions

Since the study by Leamer and Levinsohn (1995), many research initiatives have debated about the apparent inconsistency of declining trade-related costs (at least for some products) and a highly negative and significant coefficient of distance in gravity equations, which does not diminish over time. The literature has explored different explanations for this inconsistency (since with globalization one would expect the distance coefficient to decline over time), most of which are framed within the context of gravity equations, as revealed by the meta-analysis by Disdier and Head (2008).

We provide yet another explanation for this "missing globalization puzzle", as coined by Coe *et al.*

(2002), also labeled as "the conservation of distance in international trade" (Berthelon and Freund, 2008) which, in contrast to previous explanations, is not framed within the literature on gravity equations. Alternatively, we base our explanation in constructing two sets of indicators on economic integration, one of them controlling for distance, the other distance-uncorrected. These indicators are based on the geographical neutrality concept by Krugman (1996) and the Standard of Perfect International Integration by Frankel (2000).

Results indicate that the discrepancies found among both sets of indicators (distance-corrected and distance-uncorrected) have a non-negligible dynamic component, since the importance of distance increased until the mid-nineties, but has returned to 30 years ago levels. This implies that, according to our indicators, the role of distance, *on average*, is still there.

However, it is a more interesting result that discrepancies among distance-corrected and distance-uncorrected indicators differ a great deal across countries, i.e., the effect of distance is there, but the impact on each country's level of integration is varying. A mere cursory look to the different levels on integration for the different countries in our sample will promptly suggest that the pattern might not be entirely random. Accordingly, we explore some factors (without establishing a proper theory) that might explain these discrepancies, finding that GDP, specialization and regional trade agreements contribute to explain the heterogeneity. Yet for some of the explanatory variables the relationship is rather involved, since RTA membership affects distance depending on each particular RTA.

References

Alesina, A. and Spolaore, E. (1997). On the number and size of nations. *Quarterly Journal of Economics*, 112:1027–56.

Alesina, A. and Spolaore, E. (2003). *The Size of Nations*. MIT Press, Cambridge.

Anderson, J. E. (1979). A theoretical foundation for the gravity equation. *American Economic Review*, 69:106–116.

Anderson, J. E. and van Wincoop, E. (2003). Gravity with Gravitas: A Solution to the Border Puzzle. *The American Economic Review*, 93(1):170–192.

Annen, K. (2003). Social capital, inclusive networks, and economic performance. *Journal of Economic Behavior & Organization*, 50:449–463.

Arribas, I., Pérez, F., and Tortosa-Ausina, E. (2009). Measuring globalization of international trade: Theory and evidence. *World Development*, 37(1):127–145.

Berthelon, M. and Freund, C. (2008). On the conservation of distance in international trade. *Journal of International Economics*, 75:310–320.

Brun, J., Carrere, C., Gillaumont, P., and de Melo, J. (2005). Has distance died? Evidence from a panel gravity model. *World Bank Economic Review*, 19:99–120.

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

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

Coe, D. T., Subramanian, A., Tamirisa, N. T., and Bhavnani, R. (2002). The missing globalization puzzle. Working Paper 02/171, IMF, Washington.

Combes, P.-P. (2008). Gravity models. In Durlauf, S. and Blume, L., editors, *The New Palgrave Dictionary of Economics*, volume forthcoming. Macmillan, London.

Deardorff, A. (1998). Determinants of Bilateral Trade: Does Gravity Work in a Neoclassical World? *The Regionalization of the World Economy*, pages 7–22.

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

Evenett, S. and Keller, W. (2002). On theories explaining the success of the gravity model. *Journal of Political Economy*, 110:281–316.

Feenstra, R. C., Markusen, J. R., and Rose, A. K. (1998). Undertstanding the home market effect and the gravity equation: The role of differentiating goods. Working Paper 6804, NBER, Cambridge, Massachusetts.

Feenstra, R. C., Markusen, J. R., and Rose, A. K. (2001). Using the gravity equation to differentiate among alternative theories of trade. *Canadian Journal of Economics*, 34(2):430–447.

Frankel, J. A. (2000). Globalization of the economy. Working Paper 7858, NBER, Cambridge, Massachusetts.

Greenaway, D. and Milner, D. (2002). Regionalism and gravity. *Scottish Journal of Political Economy*, 49(5):574–585.

Hanneman, R. and Riddle, M. (2005). Introduction to Social Network Methods. Technical report, University of California at Riverside, Department of Sociology.

Head, K. and Mayer, T. (2002). Illusory border effects: distance mismeasurement inflates estimates of home bias in trade. Working Paper 01, CEPII, Paris.

Henderson, D. and Millimet, D. (2008). Is Gravity Linear? *Journal of Applied Econometrics*, 23:137–172.

Hummels, D. (1999). Have interational transport costs declined? University of Chicago.

Hummels, D. and Levinsohn, J. (1995). Monopolistic competition and international trade: Reconsidering the evidence. *Quarterly Journal of Economics*, 110(3):799–836.

Iapadre, L. (2006). Regional integration agreements and the geography of world trade: measurement problems and empirical evidence. In De Lombaerde, P., editor, *Assessment and Measurement of Regional Integration*, pages 65–85. Routledge, London.

Kali, R. and Reyes, J. (2007). The architecture of globalization: a network approach to international economic integration. *Journal of International Business Studies*, 38:595–620.

Karlin, S. and Taylor, H. M. (1975). *A First Course in Stochastic Processes*. Academic Press, New York.

Krugman, P. R. (1996). Regionalism versus multilateralism: analytical notes. In de Melo, J. and Panagariya, A., editors, *New Dimensions in Regional Integration*, CEPR, chapter 3, pages 58–89. Cambridge University Press, Cambridge.

Kunimoto, K. (1977). Typology of trade intensity indices. *Hitotsubashi Journal of Economics*, 17(2):15–32.

Leamer, E. and Levinsohn, J. (1995). International Trade Theory: The Evidence. *Handbook of International Economics*, 3:1339–1394.

Maddison, A. (2001). The World Economy: A Millenial Perspective. Development Centre Studies, OECD.

McLuhan, M. and Fiore, Q. (1968). *War and Peace in the Global Village: An Inventory of the Current Spastic Situations That Could Be Eliminated by More Feedforward*. Bantam Books/Random House, New York.

O'Rourke, K. H. and Williamson, J. G. (1999). *Globalization and History: The Evolution of a 19th Century Atlantic Economy*. MIT Press, Cambridge, Massachusetts.

O'Rourke, K. H. and Williamson, J. G. (2002). When did globalization begin? *European Review of Economic History*, 6:23–50.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics*, 48:7–35.

Rose, A. (2000). One money, one market: the effect of common currencies on trade. *Economic Policy*, 15(30):7–46.

Samuelson, P. (1954). The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments. *The Economic Journal*, 64(254):264–289.

Wasserman, S. and Faust, K. (1992). *Social Network Analysis: Methods and Applications*. Number 8 in Structural Analysis in the Social Sciences. Cambridge University Press, Cambridge.

Wellman, B. and Berkovitz, S. (1988). *Social Structure*. Cambridge University Press, Cambridge.

Table 1: *DGO*, *DGBC*, *DGI*, non-corrected and distance-corrected indices (%)

Year	$DGO^{\theta=1}$	$DGO^{\theta=0}$	$DGBC^{\theta=1}$	$DGBC^{\theta=0}$	$DGI^{\theta=1}$	$DGI^{\theta=0}$
1967	8.03	12.13	57.66	82.42	20.30	30.41
1968	8.44	12.91	58.96	83.90	21.02	31.53
1969	8.90	13.67	58.26	84.22	21.32	32.45
1970	9.53	14.65	60.38	83.21	22.34	33.30
1971	9.53	14.70	59.46	84.60	22.22	33.47
1972	9.80	15.31	61.12	86.20	22.78	34.37
1973	11.04	17.34	63.97	86.67	24.76	36.83
1974	13.27	20.87	64.29	87.24	27.37	40.49
1975	12.25	18.94	62.56	88.11	26.00	38.97
1976	12.76	20.02	63.04	89.04	26.58	40.13
1977	12.81	20.59	62.74	89.52	26.62	40.66
1978	12.87	21.79	65.23	90.72	27.26	42.13
1979	14.18	22.81	65.55	90.69	28.73	43.38
1980	15.11	24.20	66.32	89.38	30.04	44.40
1981	14.63	24.75	66.93	89.05	29.63	44.59
1982	14.07	23.33	67.57	88.69	29.02	43.27
1983	13.84	23.58	66.90	89.65	28.55	43.51
1984	14.63	25.73	67.75	90.66	29.69	45.53
1985	14.25	24.92	67.33	89.78	29.10	44.48
1986	13.53	25.66	67.13	89.66	28.24	44.66
1987	13.99	26.69	68.02	90.07	28.92	45.82
1988	14.18	28.25	69.47	91.44	29.53	47.56
1989	14.62	28.33	70.38	91.28	30.13	47.85
1990	14.81	27.42	70.27	90.67	30.43	47.21
1991	14.52	27.84	69.63	90.82	30.14	47.58
1992	14.54	28.20	68.84	90.66	30.14	47.97
1993	14.38	29.61	67.11	90.16	29.55	48.81
1994	15.25	31.12	67.03	90.15	30.32	50.11
1995	16.38	32.42	67.16	89.76	31.37	51.13
1996	16.61	30.60	67.47	89.42	31.73	49.90
1997	17.51	31.63	66.90	89.08	32.47	50.67
1998	17.47	30.59	66.99	89.45	32.39	50.09
1999	17.41	31.24	67.20	89.29	32.40	50.61
2000	18.85	34.37	67.70	88.78	33.74	52.80
2001	18.28	31.44	67.66	89.54	33.12	51.08
2002	18.24	30.35	66.87	89.56	32.98	50.13
2003	18.78	30.38	65.89	89.48	33.19	49.91
2004	20.12	32.01	65.22	89.08	34.16	50.93
2005	20.84	32.27	67.10	88.80	35.48	50.96

Table 2: Determinants of the distance effect, degree of openness, 1967–2005

	Dependent variable: $DO^{\theta=1}/DO^{\theta=0}$				
	Model 1	Model 2	Model 3	Model 4	Model 5
Coefficients					
(Intercept)	−1.194***	−1.162***	−1.164***	−1.184***	−1.218***
	(0.218)	(0.218)	(0.218)	(0.218)	(0.218)
GDP	0.206***	0.205***	0.204***	0.205***	0.209***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
$ENERGY$	−0.461***	−0.443***	−0.429***	−0.496***	−0.496***
	(0.111)	(0.111)	(0.111)	(0.112)	(0.111)
$REFINED$	0.994***	0.970***	0.916***	1.082***	1.011***
	(0.276)	(0.277)	(0.278)	(0.279)	(0.276)
$YRTA$	−0.004***	−0.004***	−0.004***	−0.004***	−0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
EU	−0.091***				
	(0.031)				
$NAFTA$		−0.066			
		(0.051)			
$ASEAN$			−0.122*		
			(0.065)		
$MERCOSUR$				−0.164***	
				(0.060)	
RTA					−0.096***
					(0.024)
Summaries					
R^2	0.845	0.844	0.845	0.845	0.845
$\bar{R}^2$	0.841	0.840	0.840	0.840	0.841
σ	0.251	0.251	0.251	0.251	0.250
F	193.4	192.7	192.9	193.3	194.2
p	0.000	0.000	0.000	0.000	0.000
Log-likelihood	−50.2	−53.8	−52.9	−50.9	−46.7
Deviance	140.7	141.2	141.1	140.8	140.3
AIC	230.5	237.7	235.8	231.7	223.3
BIC	603.6	610.8	608.9	604.9	596.5
N	2301	2301	2301	2301	2301

*, ** and *** denote significance at 10%, 5%, and 1% significance levels, respectively.

Table 3: Determinants of the distance effect, degree of direct connection, 1967–2005

	Dependent variable: $DBC^{\theta=1}/DBC^{\theta=0}$				
	Model 1	Model 2	Model 3	Model 4	Model 5
Coefficients					
(Intercept)	3.412***	3.333***	3.225***	3.369***	3.327***
	(0.365)	(0.366)	(0.352)	(0.366)	(0.367)
GDP	−0.125***	−0.124***	−0.113***	−0.123***	−0.120***
	(0.023)	(0.023)	(0.022)	(0.023)	(0.023)
$ENERGY$	−0.070	−0.115	−0.008	−0.019	−0.117
	(0.185)	(0.185)	(0.178)	(0.189)	(0.187)
$REFINED$	1.921***	1.983***	1.319***	1.771***	1.970***
	(0.463)	(0.464)	(0.449)	(0.469)	(0.465)
$YRTA$	−0.006***	−0.005**	−0.002	−0.005**	−0.005**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
EU	0.226***				
	(0.052)				
$NAFTA$		0.175**			
		(0.085)			
$ASEAN$			−1.441***		
			(0.105)		
$MERCOSUR$				0.304***	
				(0.101)	
RTA					0.015
					(0.041)
Summaries					
R^2	0.667	0.665	0.690	0.666	0.664
$\bar{R}^2$	0.658	0.655	0.682	0.656	0.655
σ	0.420	0.421	0.405	0.421	0.422
F	71.1	70.4	79.2	70.7	70.2
p	0.000	0.000	0.000	0.000	0.000
Log-likelihood	−1236.3	−1243.8	−1152.7	−1241.3	−1245.9
Deviance	394.6	397.1	366.9	396.3	397.9
AIC	2602.5	2617.6	2435.5	2612.6	2621.8
BIC	2975.7	2990.8	2808.6	2985.7	2995.0
N	2301	2301	2301	2301	2301

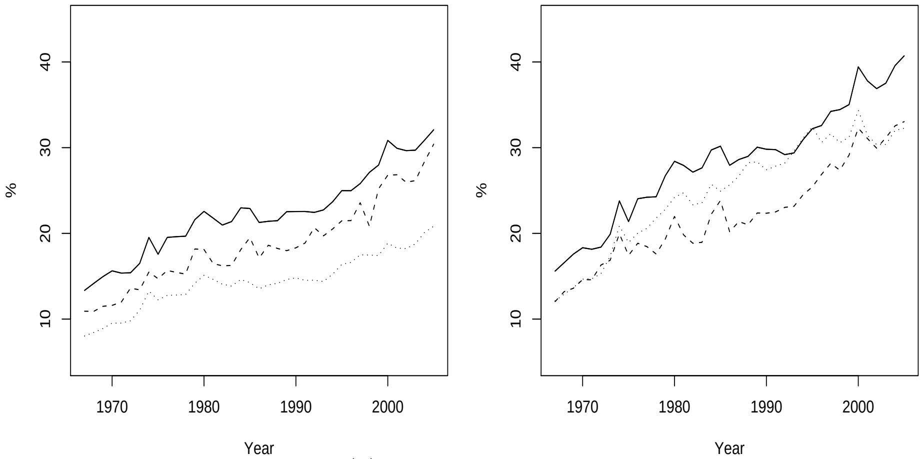
*, ** and *** denote significance at 10%, 5%, and 1% significance levels, respectively.

Table 4: Determinants of the distance effect, degree of integration, 1967–2005

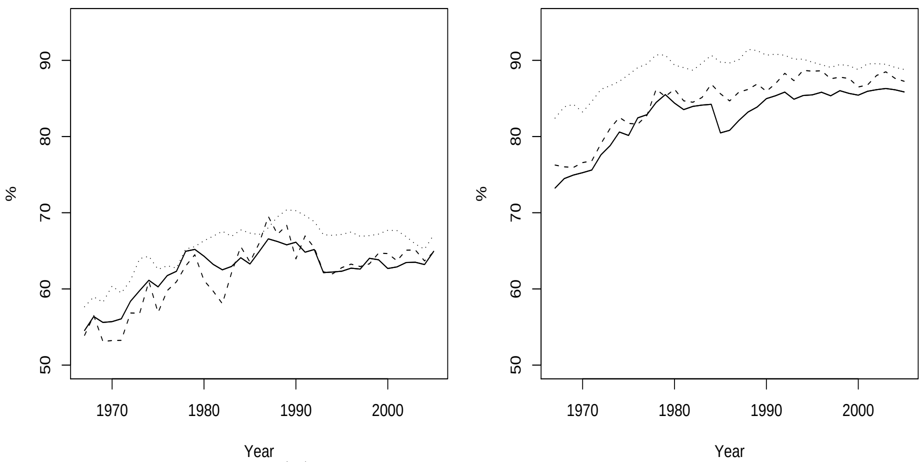
	Dependent variable: $DI^{\theta=1}/DI^{\theta=0}$				
	Model 1	Model 2	Model 3	Model 4	Model 5
Coefficients					
(Intercept)	1.654***	1.621***	1.590***	1.631***	1.644***
	(0.119)	(0.120)	(0.117)	(0.120)	(0.120)
GDP	0.004	0.004	0.008	0.005	0.003
	(0.008)	(0.008)	(0.007)	(0.008)	(0.008)
$ENERGY$	−0.121**	−0.140**	−0.114*	−0.109*	−0.117*
	(0.060)	(0.061)	(0.059)	(0.062)	(0.061)
$REFINED$	1.024***	1.051***	0.881***	0.980***	1.029***
	(0.151)	(0.152)	(0.149)	(0.153)	(0.152)
$YRTA$	−0.005***	−0.005***	−0.004***	−0.005***	−0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
EU	0.097***				
	(0.017)				
$NAFTA$		0.078***			
		(0.028)			
$ASEAN$			−0.366***		
			(0.035)		
$MERCOSUR$				0.102***	
				(0.033)	
RTA					0.046***
					(0.013)
Summaries					
R^2	0.789	0.787	0.796	0.787	0.787
$\bar{R}^2$	0.783	0.781	0.790	0.781	0.781
σ	0.137	0.138	0.135	0.138	0.137
F	132.7	130.8	138.5	131.0	131.2
p	0.000	0.000	0.000	0.000	0.000
Log-likelihood	1344.4	1331.7	1383.2	1332.6	1333.9
Deviance	41.9	42.3	40.5	42.3	42.3
AIC	−2558.8	−2533.4	−2636.3	−2535.2	−2537.7
BIC	−2185.6	−2160.3	−2263.2	−2162.0	−2164.6
N	2301	2301	2301	2301	2301

*, ** and *** denote significance at 10%, 5%, and 1% significance levels, respectively.

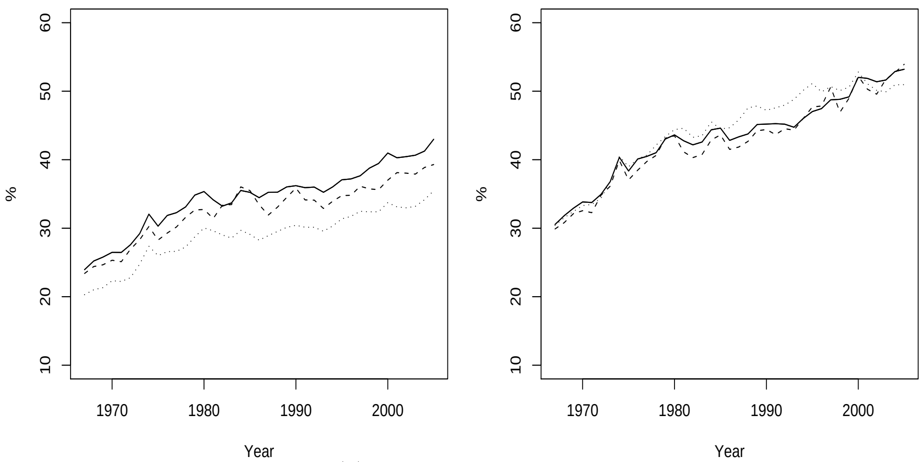
Figure 1: Degree of openness (DO), degree of balanced connection (DBC) and degree of integration (DI), 1967–2005



(a) Degree of openness



(b) Degree of balanced connection



(c) Degree of integration

—— Unweighted mean ------ Median ······· Weighted mean

Figure 2: The role of distance, time trend (1967–2005)

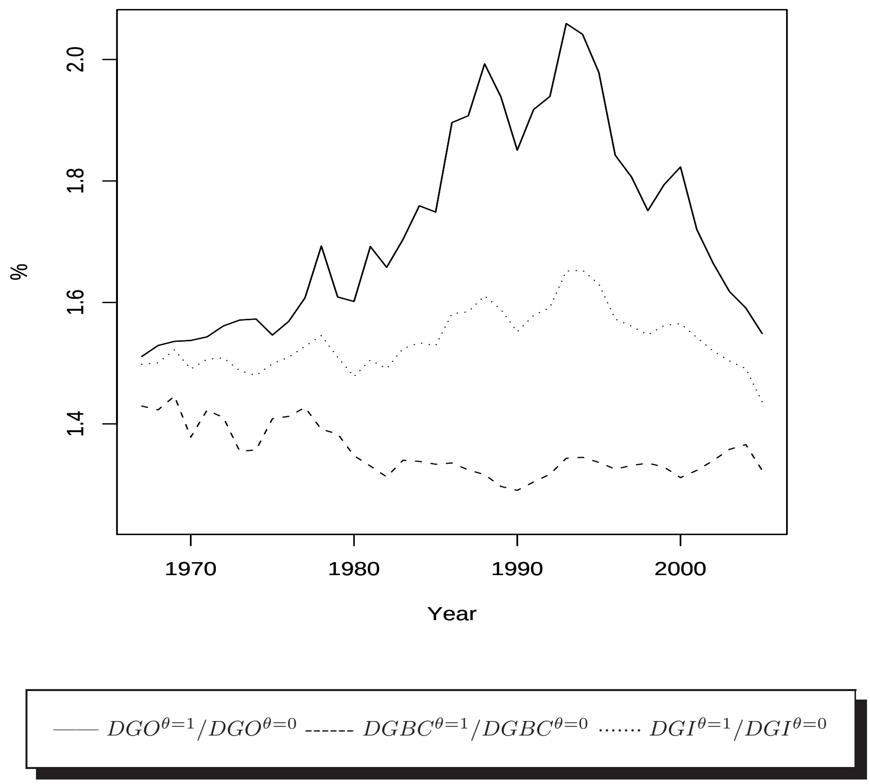
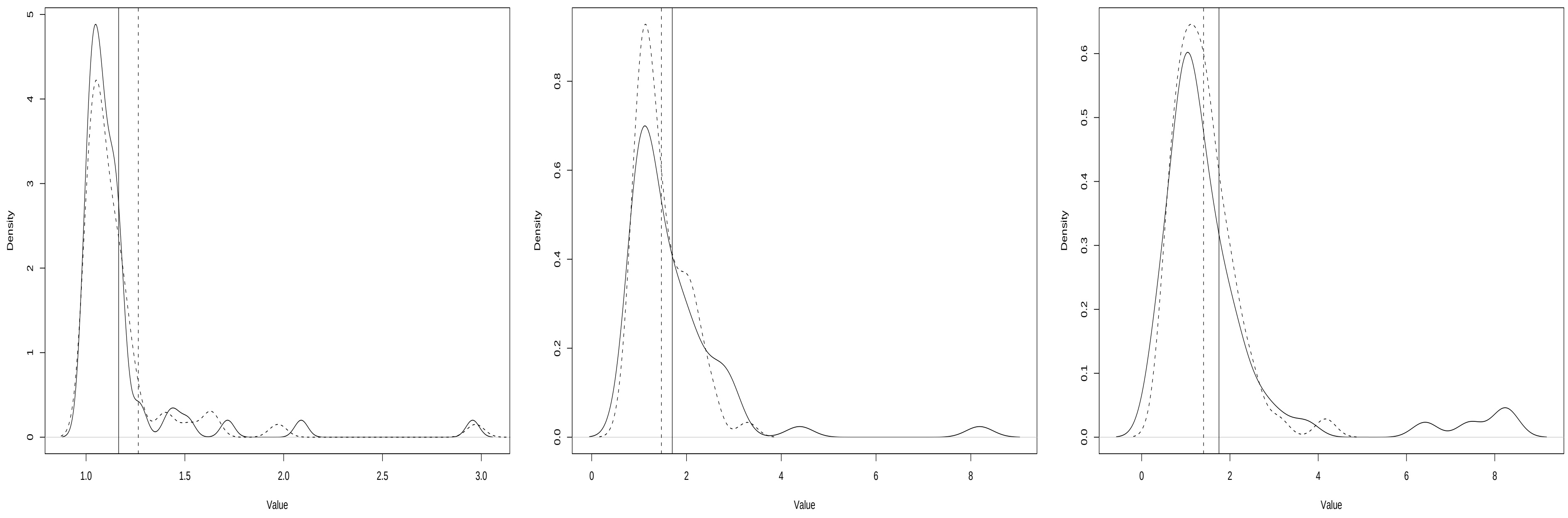


Figure 3: The role of distance, 1967 vs. 2005



a) $DO^{\theta=1}/DO^{\theta=0}$

b) $DBC^{\theta=1}/DBC^{\theta=0}$

c) $DI^{\theta=1}/DI^{\theta=0}$