Has Distance Died? Evidence from a panel Gravity Model*

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June 2002

Abstract

This paper reports panel gravity estimates of aggregate bilateral trade for 130 countries over the period 1962-96 in which the coefficient of distance is allowed to change over time. In a standard specification in which transport costs are proxied by distance only, it is found paradoxically that the absolute value of the elasticity of bilateral trade to distance has been significantly increasing. The result is attributed to a relatively larger decline in costs independent of distance (such as handling) than in distance-related costs (e.g. oil price). An extended version of the model that controls for these two factors eliminates this positive trend without reversing it. However, when the sample is split into two groups ('rich-rich' and 'poor-poor'), the paradox is maintained for the 'poor-poor' group. While not conclusive, these results are consistent with the view that poor countries may have been marginalized by the current wave of globalization.

Jel Classification: F12

*Helpful comments from particpants at seminars at CERDI and WTO are gratefully acknowledged. Agnès Bénassy-Quere, Olivier Cadot, Paul Collier, Marcel Fafchamps, Maurice Schiff, Alan Winters gave helpful comments on an earlier draft.

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'The death of distance will not only erode national borders; it will reduce the handicaps that have up until now burdened fringe countries. That will be of enormous importance for the many small countries that have come into existence in the past half century. As a result, one economic argument against secession will be eroded.'

F. Cairncross, 1997, p.26

1 Introduction

The 'integrated equilibrium' view of the world whereby transport and communication revolutions should lead to a dispersion of economic activity did not occur with the reduction in transport costs during the first wave of globalization in the 19^{th} century. Yet, as the above quote illustrates, there is a widespread perception that the second wave of globalization associated with the recent information and communication technologies (ICT) revolution should lead to an integrated equilibrium view of the 'death of distance'. Indeed, in the post second world war era, the world trade output ratio has grown at 2.9% per year and the manufacturing trade/manufacturing output and FDI/ output ratios at 3.7% and 3.0% per year respectively (Hummels, Ishi and Yi, 2000). And in assessing the consequences of the current wave of globalization for workers, the World Bank's 1995 World Development Report estimated that, by 2000, only 10% of the world labor force would be sheltered from foreign competition, instead of 70% in 1950.

Remarkably, whether bilateral trade, M_{ij}, is for goods and services, for FDI flows, or for cross-border equity flows, in a formulation of the form $M_{ij} = X_i(D_{ij})^{\beta}X_j$ where $X_i(X_j)$ denotes importer (exporter) country characteristics, the elasticity of bilateral trade with respect to distance, β, is always significant, and estimated in the range $0.8 < |\beta| < 1.3$. If the second wave of globalization implies a death of distance, then, the estimated absolute value of this coefficient should fall.

A growing literature is starting to give very useful, but piecemeal, information on the evolution of transaction costs as barriers-to-trade. Hummels (1999b) observes that modal use is consistent with relative cost movements (substitution of aircargo for ocean shipping). Based on German shipping data he concludes that, despite containerization which has lowered the price of long routes to short routes, because the price of bulk commodities has fallen faster than unit cost of tramp shipping, the ad-valorem barrier to trade due to ocean transport costs has not declined over the past 40 years. However, using US customs data at the 5 digit SITC level over the period 1974-98, after controlling for distance, Hummels finds that air and shipping freight rates have been falling through time (more on this below).[1]

While very informative, this is still only partial evidence, and it really does not tell us whether globalization is reflected in a 'death of distance' as is so often claimed in the popular press. To our knowledge, there is no broad time-series evidence on the evolution of transport costs in world trade.[2] In preliminary work, based on a gravity model, Brun, Guillaumont, de Melo (1999) found, paradoxically, that the elasticity of bilateral trade with respect to distance has increased over time. As recognized by them (also see Frankel, 1997), it is not the average, but the marginal cost of distance, i.e. the increase of transportation cost due to a marginal increase of distance, that is relevant to explain the marginal impact of distance on trade. Transaction costs in general, and transport costs in particular, have a component that is 'independent of distance', and a component that is 'linked to distance'. Then, a decrease of transport costs independent of distance lowers average transport costs, and leads, for a given marginal cost, to an increase in the elasticity of the transport costs with respect to distance, then to an increase of the absolute value of the elasticity of trade with respect to distance.

We develop this interpretation of the changing role of distance by estimating a standard gravity model of aggregate bilateral trade flows using panel data for 130 countries over the period 1962-1996, thus allowing us to span the whole period over which the globalization debate takes place. Section 2 develops an 'augmented' trade-barrier function and introduces it in a panel gravity model. Section 3 discusses the econometric method. Sec-

[1] In a more recent work – again based on US data – Hummels estimates that the cost of an extra day in transit is between 0.3% and 0.5% of the value of the good shipped (Hummels, 2001) and finds an elasticity of freight rates to distance between 0.2 and 0.4, a figure close to the estimate of Limao and Venables (2002) for identical-sized container shipments from Baltimore to 64 destinations around the world.

[2] An exception is Baier and Bergstrand (2001). Applying a standard gravity model to a sample of 16 developed countries, they estimate that 25% of the growth in trade is attributable to the reduction in protection, 67% to income growth and 8% to decline in transport costs. Also see Brun, Guillaumont and de Melo (1999).

tion 4 reports the results, first for a 'standard' barrier-to-trade function used in gravity models, then for the augmented trade-barrier function presented here.

To anticipate our main conclusions, it turns out that, for the sample as a whole, the absolute value of the elasticity of bilateral trade with respect to distance, far from evidencing the death of distance, does increase in the standard model, and remains constant in the augmented model. However, when the sample is split into low and high income countries, according to the augmented model, this elasticity is still found to increase for bilateral trade between low income countries, while it falls for bilateral trade between high income countries. We speculate that this result may reflect the fact that low income countries have been marginalized in the recent wave of globalization. Section 5 concludes.

2 Barriers-to-trade in the gravity model

Whether one assumes product differentiation at the firm level as in the monopolistic competition model, or at the national level as in the perfect-competition H-O type model under the assumption of complete specialization at the country level, utility maximization yields a standard 'generalized' gravity equation of the form[3]:

$$M_{ij} = \frac{Y_i Y_j}{Y_W} \theta_{ij}^{-\sigma} e_{ij}^{-\sigma} \left[\frac{\dfrac{(p_j)^{-\sigma}}{\left(\overline{P}_i\right)^{1-\sigma}}}{\left(\overline{\overline{P}}_i\right)^{1-\sigma}} \right] \qquad i, j, h = 1, ..., n \tag{1}$$

which says that the intensity of imports of i from j depends on the product of partners' income, $Y_i Y_j$, relative to the world income, Y_W, on the barriers-to-trade (and hence distance) between i and j, θ_{ij}, on the bilateral nominal exchange rate, e_{ij}, and on prices in the country of origin, p_j, relative to the price level , $\overline{P_i}$, in the country of destination deflated by an expenditure-share-weighted trading partner average price index $\overline{\overline{P_i}}$. Expression (1) shows

[3] Appendix A2.1 derives (1).

that the elasticity of bilateral trade to transport costs ($-\sigma$) hinges on the ease of substitution across suppliers.

In the gravity model, transaction costs are approximated indirectly via estimation of a 'trade barrier function'.[4] A general formulation of transaction costs for commodity k shipped between i and j in period t, can be written as:

$$\theta_{ijt}^{k} = T(td_t, f_t^k, x_{ij}, X_{it}, X_{jt}, \mu_{ij}) \tag{2}$$

In (2), x_{ij} is the vector of characteristics relating to the journey between i and j, X_{it} and X_{jt} are country-specific characteristics, td_t is a vector of variables that captures the components of costs that are time-dependent and, f_t^k is a vector of characteristics relating to the commodity composition of bilateral trade. Finally, μ_{ij} represents the unobservable variables constant over time (to be captured in the estimation by the use of bilateral specific effects).

2.1 The standard trade barrier function

We start with a standard trade barrier function, then we propose an augmented version. In the standard implementation of (2), the 'trade-barrier' function includes distance in the vector of characteristics, x_{ij}, as well as a dummy variable for common border and common language. Among the country characteristics, X_{it} and X_{jt}, typically, dummy variables are used to control for a country that is landlocked or an island. Assuming a multiplicative form, a standard static 'trade-barrier function'can be written as:

$$\theta_{ij} = (D_{ij})^{\gamma} e^{\delta_1 LAN_{ij} + \delta_2 L_{ij} + \delta_3 E_i + \delta_4 E_j} = (D_{ij})^{\gamma} \exp^{\lambda} \tag{3}$$

[4] It would be natural (and tempting) to proceed from the available cif-fob price data. In our sample, it turns out that cif prices are below fob prices for 42% of the observations. More on this in Hummels (1999b, appendix 3).

$\gamma > 0$ is the elasticity of transport costs to distance. In (3), D_{ij} is distance between i and j, with the remaining variables, dummies that relate to trade-cost savings: LAN_{ij} for common language ($\delta_1 < 0$), L_{ij} for a common border ($\delta_2 < 0$), $E_{i(j)}$ for landlockedness ($\delta_{3(4)} > 0$). Note that this specification, retained here, implies that the marginal effect of a change in one cost depends on all other costs.

Estimation of the standard trade barrier function boils down to plugging (3) into a modified version of (1) that includes the income per capita (to capture Engel effects) and population (a proxy for supply side effects reflecting differences in factor endowments) as in e.g. Bergstrand (1989). We note the two variables of population that are introduced N_i and N_j.

Furthermore, when estimating a gravity model on panel data with a long time dimension (35 years in our case), it is essential to capture relative prices effects. According to (1), one should introduce relative prices of domestically produced goods and foreign produced competing goods. For a large sample of countries, representative price indexes are not available, and the best one can do is to use real exchange rate indexes which have at least the merit of isolating the effects of changes in nominal exchange rates. Therefore, as in e.g. Baier and Bergstrand (2001), we introduce the bilateral real exchange rate between i and j, RER_{ijt}, to capture the evolution of relative prices in (1).

The panel data set allows us to estimate more accurately the elasticity of trade with respect to distance. First, bilateral specific effects are included to capture all non observable characteristics of the bilateral relationships. However, contrary to these authors, the bilateral specific effects are modeled as random effects which allow the estimation of the coefficients for variables that are cross-sectional time-invariant (as in Brun, Guillaumont and de Melo, 1999, Carrère, 2002, and Egger and Pfaffermayr, 2000).

Second, because we are interested in the 'death of distance', we allow the elasticity of trade with respect to distance, β, to change over time, but not across countries (though later we allow for differences across countries by splitting the sample into groups). According to (1) and (3), $\beta = -\sigma\gamma$. Assuming that γ_t (and then β_t) can be approximated by a quadratic time trend (t) yields:

$$\theta_{ijt} = (D_{ij})^{\gamma_1} (tD_{ij})^{\gamma_2} \left(t^2 D_{ij}\right)^{\gamma_3} \exp^{\lambda} \tag{4}$$

In this formulation, the elasticity of transport costs to distance, γ_t, is given by:

$$\gamma_t \equiv (\partial\theta_{ijt}/\theta_{ijt})/(\partial D_{ij}/D_{ij}) = \gamma_1 + \gamma_2 t + \gamma_3 t^2$$

Taking into account (4), the modifications to (1) discussed above, and using the standard multiplicative form yields the standard gravity model.

2.2 An augmented trade barrier function

We go beyond the specification (4) by including the following factors that affect the estimated barriers to trade. First, we isolate in the vectors $X_{i(j)t}$ an index of the quality of infrastructure in period t, $K_{i(j)t}$, with larger values of the index meaning a better infrastructure.[5] Second, we include variables entering in td_t and f_t^k. The cost of fuel P_{Ft} is the main factor to be considered among variables that are time-dependent (variations in trade policy are partly captured via the inclusion of RER_{ijt}). For f_t^k, we include a proxy for freight costs related to weight approximated by introducing the share of primary products in total exports π_{ijt}[6].

The barriers-to-trade function in (4) becomes:

$$\theta_{ijt} = (K_{ijt})^{\rho_1} (P_{Ft})^{\rho_2} (\pi_{ijt})^{\rho_3} (D_{ij})^{\gamma_1} (tD_{ij})^{\gamma_2} \left(t^2 D_{ij}\right)^{\gamma_3} e^{\lambda} \tag{5}$$

with the following expected signs: $\rho_1 < 0, \rho_2 > 0, \rho_3 > 0,$ and again:

$$\gamma_t \equiv (\partial\theta_{ijt}/\theta_{ijt})/(\partial D_{ij}/D_{ij}) = \gamma_1 + \gamma_2 t + \gamma_3 t^2$$

[5] The index is constructed from data in Canning (1996), and includes roads, telephone lines, and railways (see appendix A.1 for the source and transformation of the data). Appendix A3 shows the evolution of the series.

[6] Including the mode of transport would also be desirable but is not available for such a large sample.

This gives us the 'augmented' gravity model:

$$\begin{aligned}\ln M_{ijt} &= \alpha_0 + \alpha_1 \ln Y_{it} + \alpha_2 \ln Y_{jt} + \alpha_3 \ln N_{it} + \alpha_4 \ln N_{jt} + \alpha_5 \ln RER_{ijt} \\ &\quad + \beta_1 \ln D_{ij} + \beta_2 \ln (tD_{ij}) + \beta_3 \ln \left(t^2 D_{ij}\right) + \alpha_6 L_{ij} + \alpha_7 E_i + \alpha_8 E_j \\ &\quad + \alpha_9 \ln K_{ijt} + \alpha_{10} \ln P_{Ft} + \alpha_{11} \ln \pi_{ijt} + \alpha_{12}\ t + \mu_{ij} + \nu_{ijt} \qquad (6)\end{aligned}$$

The expected signs are:

$\beta_1 < 0$, $\alpha_1 > 0$, $\alpha_2 > 0$, $\alpha_3 < 0$, $\alpha_4 < 0$, $\alpha_5 < 0$, $\alpha_6 > 0$, $\alpha_7 < 0$, $\alpha_8 < 0$, and $\alpha_9 = -\sigma.\rho_1 > 0$, $\alpha_{10} = -\sigma.\rho_2 < 0$ and $\alpha_{11} = -\sigma.\rho_3 < 0$. Since we will be comparing results obtained from the augmented specification with those under the standard specification, note that the standard specification excludes the first three explanatory variables in the third line of (6).

For most authors, β_1 is interpreted as an estimate of barriers to trade, although some (e.g., Rauch, 1999) also consider this coefficient as an estimate of search costs. According to the functional form in (6) , the elasticity of bilateral trade with respect to distance, β_t, is given by:

$$\beta_t \equiv (\partial M_{ijt}/M_{ijt})/(\partial D_{ij}/D_{ij}) = \beta_1 + \beta_2 t + \beta_3 t^2 \qquad (7)$$

To understand the evolution of β_t, it is useful to compare the standard and augmented trade barrier formulations. According to (1) and (4) or (5), the elasticity of bilateral trade to distance is given by $\beta_t = -\sigma.\gamma_t$ so that the evolution of β_t depends on the evolution of the elasticity of transport costs with respect to distance γ_t. As the standard barriers-to-trade function is misspecified, the observed evolution of β_t will be governed by variables included in (5). Decompose then transaction costs in (5) into two components, one linked to distance, θ^D_{ijt}, and one independent of distance, θ^I_{ijt}. If the technology underlying these two components of transport costs is Leontief, then one can write:

$$\theta_{ijt} = \theta^D_{ijt} \left(P_{Ft}, \pi_{jt}\right) + \theta^I_{ijt} \left(K_{ijt}, \pi_{jt}\right) \qquad (8)$$

Costs related to distance depend primarily on the evolution of the price of energy (P_{Ft}), but also on the commodity composition of trade, π_{ijt}. As data on bilateral trade for primary products are unavailable, we proxy π_{ijt} by π_{jt} (share of primary export products in total exports for country j regardless of destination). Countries that export bulky products such as primary commodities will see their transport costs more heavily dependent on distance. These assumptions are summarized in (9):

$$\theta_{ijt}^{D} = g\left(D_{ij}.P_{Ft}, D_{ij}.\pi_{jt}\right); \qquad \partial g\left(.\right)/\partial P_{Ft} > 0, \quad \partial g\left(.\right)/\partial \pi_{jt} > 0 \tag{9}$$

In this model, costs independent of distance will be primarily affected by the evolution of the quality of infrastructure in both partners, captured here by K_{ijt}. One could also presume that unit-handling costs are likely to be lower for bulk than for differentiated manufactured goods. Then, these assumptions are summarized in (10):

$$\theta_{ijt}^{I} = f\left(K_{ijt}, \pi_{jt}\right); \qquad \partial f\left(.\right)/\partial K_{ijt} < 0, \quad \partial f\left(.\right)/\partial \pi_{jt} < 0 \tag{10}$$

¿From (9), (10) and the definition of γ_t it follows that the elasticity of transport costs with respect to distance, γ_t is:

$$\gamma_t = \frac{g\left(D_{ij}.P_{Ft}, D_{ij}.\pi_{jt}\right)}{f\left(K_{ijt}, \pi_{jt}\right) + g\left(D_{ij}.P_{Ft}, D_{ij}.\pi_{jt}\right)} \tag{11}$$

Total differentiation of (11), under the assumptions about partial derivatives in (9) and (10), leads to the conclusion that one can expect the distance elasticity of transport costs (γ_t) to increase over time[7] (and consequently also

[7] Appendix A2.2 gives the expression for $\partial\gamma_t/\partial t$ and reports the impact of each factor on the expected sign of $\partial\gamma_t/\partial t$ as well as the evolution of the variables P_{Ft} and K_{ijt} and π_{jt}.

the absolute value of the distance elasticity of bilateral trade $\partial|\beta_t|/\partial t > 0$) when, other things being equal[8]:

- the real price of oil (P_{Ft}) increases,
- the quality of infrastructures (K_{ijt}) increases,
- the relative share (π_{jt}) of commodities in the total exports from j increases.

Since (see appendix A.3) P_{Ft} and K_{ijt} actually increased and π_{jt} actually decreased over the period considered, P_{Ft} and K_{ijt} are expected to have a positive effect and π_{jt} a negative effect, on the evolution of $|\beta_t|$ compared to its estimate in the standard model.

To sum up, in the standard model $|\beta_t|$ is a 'gross' distance elasticity of trade, in the augmented model $|\beta_t|$ is a 'residual' distance elasticity, once controlled for the direct impact on trade of some specific determinants of transport costs (oil price, infrastructure, composition of trade).

3 Estimation method

The two versions of (6) are estimated using panel data techniques for a sample of 130 countries (171,998 observations) over the period 1962-1996. Data sources and transformations are described in appendix A.1.

The estimation method uses a random effects model since the within-transformation in a fixed-effects model removes variables, such as distance, that are cross-sectional time invariant. In the absence of correlation between the explanatory variables and the specific effects, the simple GLS estimation gives consistent estimates for the coefficients of a random effects model. However, in a gravity equation, GDPs are endogenous, i.e. correlated with the specific effects.[9] One can deal with this issue in a random effect model by using the instrumental variables estimator proposed by Hausman and Taylor (1981). Letting $X(Z)$ denote the variables that vary (are invariant) over time, with $X_1(X_2)$, the endogenous (exogenous) variables, the latter being

[8] ¿From (11) one can also see that a decrease in protection reflected in a decrease in the value of $f(.)$ would also lead to an increase in the weight of distance in barriers-to-trade (note that Clark et al. (2001) argue that the decrease of protection has made more apparent the role of distance as a barrier-to-trade).

[9] Infrastructure or population variables are also likely to be endogenous (see later).

the income variables, Y_{it} and Y_{jt}. Breusch, Mizon and Schmidt (1989) suggest to use as instruments $[QX_1, QX_2, PX_1, Z]$, which are then taken within the model.[10]

Because, the resulting estimator is consistent but not efficient as it is not corrected for heteroskedasticity and serial correlation, we follow the suggestion of Hausman and Taylor (1981) and use the first-round of estimates to compute the variance of the specific effects and the variance of the error term (see e.g. Egger and Pfaffermayr, 2000). To compare the Hausman Taylor estimator with the GLS estimator, we use a test proposed by Guillotin and Sevestre (1994). The values of the Chi-square statistic for that test, turns out to be always superior to the critical value, so that the null is rejected and the Hausman Taylor estimator is preferred to the GLS estimator (see table 1).

Finally, as the data set covers a long time span, some series may contain a unit root in which case the estimates in the table 1 would be spurious if the relations were not cointegrated. So, a Levine and Lin (1993) unit root test was applied to the series for GDP, population and bilateral imports. This test rejects, very significantly, for all series, the null of a unit root.

4 Results

First, we discuss results for the whole sample, reported in table 1, then we turn to results for bilateral trade by group of countries, reported in table 2.

4.1 Aggregate results

Results corresponding to the standard gravity model specification appear in table 1, column 1. The overall fit is good ($R^2 = 0.52$) with the F-test indicating that the variables are jointly significant. All the variables have the expected sign and plausible values. As suggested by the theory, the elasticity of trade with respect to income is significant and close to unity. The

[10] Here Q is a matrix which obtains the deviations from individual means, and P is a matrix which averages the observations across time for each individual. See appendix A2.1 for more details on the method.

population variables have the negative expected sign, capturing the often-observed phenomenon that larger countries tend to trade a smaller percentage of GDP. Likewise, the common border dummy is positive and significant with a value close to estimates in the literature: countries that share a common border trade more than twice ($exp(0.94) = 2.55$) as the level predicted by the gravity equation. Landlockedness of the importing country (E_i) is also a significant impediment to trade. For the exporting country, the coefficient is also negative, though it is smaller and significant only at the 10% level. And the bilateral real exchange rate (RER_{ijt}) has the expected negative sign: an increase of the RER reflects a depreciation of the importing country's currency against that of the exporting country, which reduces i's imports from j. Finally, according to the standard trade-barrier specification, the elasticity of bilateral trade to distance evolves according to:

$$\beta_t \approx -1.203 - (0.0062.t) + (0.0001.t^2)$$

The variable, tD_{ij}, has a negative and significant impact on trade as β_2 takes the value of –0.0062. Thus, after controlling for the standard barriers-to-trade effects, 'distance' plays a bigger role as time passes with a turning point estimated for 1993. According to these estimates, a 10% increase in distance would reduce bilateral trade by 12.1% in 1962 and by 13.0% in 1996, i.e. an increase in the impact of distance of about 7.63% over thirty five years, instead of a decrease, as expected.

The robustness of the evolution of β_t, is tested in the following ways. First, we check if the results are sensitive to a potential endogeneity of infrastructure and population variables. The instrumentation of these variables (in addition of those of GDPs), according to the Hausman-Taylor method, does not affect the evolution of the elasticity of bilateral trade to distance.

Second, as the sample is unbalanced, we look for the presence of selection bias. Following Nijman and Verbeek (1992), we introduce three variables in the model presented in column 1, which reflect the individual's patterns in terms of presence in the sample. Even if these three variables are significant, we obtain similar estimates of β_t .[11]

[11] We add the following variables in the equation: the number of years of presence of the couple ij in the sample; a dummy that takes the value 1 if ij is observed during the entire period (0 otherwise); and a dummy that takes the value 1 if ij is present in $t-1$. See Carrère (2002) for more details on this method applied to a similar data set.

Finally, to check that the time trend does not capture tendencies in other coefficients, we estimate regressions over sub-periods of 3 years (to keep a panel data structure). The estimated coefficients plotted in appendix A.4 show that the increasing impact of distance over time is unaffected.

We have seen in section 2.2 that the evolution of β_t depends on the evolution of the elasticity of transport costs with respect to distance γ_t. Reliable (in the sense of having reliable price or cost data) estimates of γ are worth mentioning as a cross-check. Limao and Venables (2002), using 1990 transport cost data for 40 feet container shipments from Baltimore to 64 destination cities, obtain, after controlling for landlockedness only, an estimated ('true') value of γ of 0.38 in the aggregate with 0.19 for the overseas component of distance and 1.38 for the overland component (About 50% of the cross-sectional variation in their data set is accounted for by distance, dummy variables and an index of infrastructure similar to ours). Using cross-section commodity-level import shipments to the U.S. over the period 1974-98, Hummels (2001, table A1) estimates an elasticity of freight rates to distance in the range $0.2 < \gamma < 0.4$. Also using U.S. data, after controlling for port efficiency, Clark et al. (2001), obtain an estimate of 0.2. But only Hummels (1999b) allowed γ to change over time. We come back to this point later.

Table 1 here: Gravity panel estimates

Turn now to the results from the augmented trade barrier function displayed in columns 2, 3, 4 and 5 in table 1, where the variables are introduced one by one to check their sign and their impact. Reassuringly, coefficient estimates are stable across specifications.

Start with the price of oil (column 2) whose coefficient is, as expected from (6), negative and significant. Since the real price of oil increased over the period 1962-1996, introduction of P_{Ft} significantly reduces the increase of $|\beta_t|$ over time.

Column 3 tests the impact of the quality of infrastructure. As expected from (6), an improvement in the quality of infrastructure increases significantly the volume of trade[12]. The introduction of K_{ijt} also contributes to a strong decrease in the value of $|\beta_t|$. A decline in transport costs independent

[12] In Limao and Venables (2002), the infrastructure coefficient is 0.75 in OLS and 1.3 in

of distance appears to be an important factor explaining the increase of $|\beta_t|$ in the standard trade barrier specification.

Column 4 controls for the commodity composition of trade by including the share of primary products in total exports of j. Again, as expected from (6), it has a significant negative impact on trade.[13] Since π_{jt} decreases over time, we expect that the introduction of this variable increases the evolution of $|\beta_t|$. While this is so, the effect is quantitatively very small. This could be so for several reasons, one being the approximation of π_{ijt} by π_{jt}[14].

Finally, column 5 reports the results for the augmented trade-barrier function that includes jointly the three preceding variables. As expected, they are all simultaneously significant, and other coefficients are stable. Notably, as shown in figure 1, they jointly eliminate the estimated trend for β_t in column 1.[15]

Figure 1 here: The elasticity of bilateral trade to distance

Even if the augmented trade barrier function cannot control for all the factors that have been identified as contributing to the 'death of distance', the infrastructure index does include per capita telephone lines, road and railway density. With this specification which controls for the impact of some costs directly linked to distance (e.g. oil price), we are still unable to identify a declining impact of distance on bilateral trade over 35 years on a worldwide basis.[16] Since we only control indirectly (via the inclusion of a

tobit. As in their estimates, the inclusion of this variable indirectly increases the coefficient for neighbourhood (L_{ij}).

[13] Note also the significant change in the estimate of β_1, which may be due to the fact that primary commodities exporters are on average "far-away countries".

[14] Others include the impact of infrastructure improvements on costs independent of distance. These have probably been stronger for manufactures than for primary commodities. Then the primary commodity share decline may have accentuated the positive effect of the improvement of K_{ijt} on $|\beta_t|$ when K_{ijt} is not controlled for as in column 4. Likewise the correlation between π_{jt} and D_{ij} may have become stronger over time, contributing to dampen the effect initially expected.

[15] As mentioned previously, instrumenting on the infrastructure and population variables, as well as the introduction of three variables to control for selection bias, do not affect the evolution of β_t.

[16] Accounting for regional agreements via dummy variables has no effect on the estimated values for β_1, β_2 and β_3 (only values for the neighborhood coefficient, L_{ij}, are

time trend) for the declining trend in protection which would contribute to increase the weight of distance in trade barriers, it could be that not fully controlling for this factor would account for our failure to identify a declining impact of distance on the volume of bilateral trade.

4.2 Results by groups

Both to check the robustness of results and to see whether poor countries may have been marginalized in the current wave of globalization, table 2 reports results for bilateral trade among countries according to their level of development. To this end, the sample is broken down into three equal-sized groups with selection according to the income per capita of each bilateral trade partner so that 'P-P'('R-R') is bilateral trade between the poorest (richest) tercile of countries in each time period.[17] Results for the standard and the augmented trade barrier functions for the 'P-P' and 'R-R' groups are reported in table 2.

Table 2 here: Gravity Panel estimates by group

Splitting the sample reveals two differences among the sub-groups. First, the values of the coefficients that capture barriers-to-trade are much larger in absolute value for the 'P-P' sample (both in equation 1 and 5). The coefficient for landlockedness has also a larger value for 'P-P' bilateral trade, especially so for the exporting country.[18] Moreover, in equation 5, the share of primary commodities has a larger impact on the volume of trade among low-income countries than has an increase in oil price. Finally, the coefficient for infrastructure is larger for low-income countries suggesting larger returns (in terms of trade volume) when improving infrastructure in low-income countries.

altered). Agreements taken into account are European Union, MERCOSUR, ASEAN, ANDEAN, CEAO/UEMOA, UDEAC/CEMAC, CEDEAO, SADC, COMESA.

[17] A residual group, covering bilateral trade among 'rich-poor' countries as well as trade among middle-income countries, is excluded from the estimation.

[18] Not controlling for modal transport choice might explain this result. In low-income countries the bulk of trade is made of primary commodities and it is sent by ship rather than air. The difference in coefficient estimates could be due to the possibility of processing close to point of entry in the importing country while locational choice in the exporting country is limited.

Second, comparing the results between the standard and augmented trade barrier formulations (also see figure 2), the estimate of the elasticity of bilateral trade to distance through time is largely unaffected by moving to the augmented specification in the 'P-P' sample. But in the 'R-R' sample, the change over time is significantly affected: $|\beta_t|$ has a negative trend instead of the positive one observed for the standard gravity model.[19]

Figure 2 here: The elasticity of bilateral trade to distance by group

Does this suggest a 'death-of-distance' for high-income countries, and the 'marginalization' for low-income countries?

First, the diverging evolution of β_t observed in the two samples, from equation 1 to 5, can be explained by the rate of improvement of the infrastructure index which is twice as large for the high-income portion of the sample than for the low-income portion (see appendix A.3). The impact of infrastructure is, in principle, controlled for through the index K_{ijt}. But, two variables, not included in the model, having a bearing on the impact of distance, are correlated with K_{ijt}. Time in transit, which is higher for 'P-P' bilateral trade, is one such variable.[20] Another one is the mode of transport, which have more evolved for the 'R-R'. Hence, when K_{ijt} is included in equation 5, $|\beta_t|$ decreases significantly for 'R-R' whereas it is left unaffected in the 'P-P' sample.

Second, it is likely that some variables are still missing and may explain why $|\beta_t|$ finally displays a negative trend for 'R-R' (equation 5) whereas it is still largely positive for 'P-P'. One factor is the larger decline in tariffs for 'P-P' bilateral trade than for 'R-R' since 1962, which should tend to increase the elasticity of transport costs to distance for that group.[21] A second factor are bilateral FDI which have increased more rapidly for the 'R-R' and which

[19] Again, the introduction of variables checking for selection biais does not affect the evolution of β_t. However, the coefficient values for these variables are larger for the 'P-P' regressions, which would be consistent with some remaining specification problems.

[20] Using shipments to the US, Hummels (2001) estimates for manufactures that the cost of an extra day in transit at 0.5% of the value shipped. At equal distance, time in transit is higher for 'P-P' bilateral trade, in part because ships travel routes less frequently.

[21] Although the model includes a time trend, adding this factor could contribute to lower the evolution of $|\beta_t|$ for the 'P-P' group.

are correlated with any one of the factors independent of distance included in the model.

Finally, as a robustness check, it is instructive to compare our results with those obtained by Hummels (1999b) for freight rate estimates for US imports at the commodity level over the period 1974-98. In an equation in which freight rates costs are estimated as a function of weight, distance, commodity fixed effects, and a time trend (and a time-trend squared) for the distance coefficient, he finds that the distance coefficient falls with respect to time, but only after containers are introduced, i.e. starting in 1980. We have reestimated equations 1 and 5 for the US imports from the world and over 1980-96. We get the same results as Hummels (1999b), namely a falling coefficient of distance over time for the imports of U.S over 1980-96.[22] Of course, this is only very indirect evidence that an augmented trade barrier function in a gravity equation may capture some of the determinants of transport costs isolated in a more reliable data set, but it is reassuring, nonetheless.

5 Conclusion

This paper has used a panel gravity model successively with a standard and an 'augmented' trade barrier function to estimate the impact of transport costs, and of distance in particular, on bilateral trade for the largest possible sample of countries over the period 1962-96. In spite of the many shortcomings associated with gravity-based indirect estimates of transport costs, several intuitively plausible results emerge from the models estimation: an elasticity of trade with respect to income close to unity as suggested by theory, a significant impact of real exchange rate on the volume of bilateral trade as well as expected and significant signs for exporter and importer country characteristics. Not least, the model produces an estimate of the elasticity of trade with respect to distance that is very close to direct estimates obtained

[22] Equation 5 estimates are (t-Student in parenthesis)

$$|\partial M_{USAjt}/\partial D_{ij}| = \underset{(4,19)}{0,527} + \underset{(0,47)}{0,0066}.t - \underset{(2.39)}{0,0003}.t^2$$

$R^2 = 0.53 \quad N.Obs = 1261$

from transport cost data, and our results are consistent with those obtained with more reliable data in the case of US transport cost estimates.

The factors included in the augmented trade-barrier function (the real price of oil, an index of infrastructure, and the share of primary exports in total bilateral trade) produced statistically significant estimates. Jointly, the variables in the augmented trade barrier function, eliminate a positive and paradoxical trend for the absolute value of the elasticity of bilateral trade to distance, which was revealed in the standard trade-barrier function. Fundamentally, the evidence of this positive trend (an increasing impact of distance) was due to the lowering of the transport costs independent of distance (infrastructure component) as well as the increase of oil price, a cost related to distance. We also noted that only controlling partially for the declining trend in protection worldwide could have had an impact similar to that of the lowering of transport costs independent of distance.

Splitting the sample into three equal-sized groups according to income per capita revealed significant differences in bilateral trade coefficients estimates for low-income bilateral trade compared with high-income bilateral trade. First, the coefficients capturing barriers-to-trade, including distance, have much higher values for the 'P-P' group. Second, the absolute value of elasticity of bilateral trade to distance increases for low-income bilateral trade in the standard and in the augmented model while for high-income bilateral trade it exhibits an increase in the standard model, but a decrease in the augmented model: this result would be expected from a fall in the components of transport costs that are independent of distance, a fall stronger in the high income, than in the low income countries. Even though statistical problems persist because of lack of more reliable data, the results from this sample-splitting procedure are consistent with recent echoes that poor countries may have been marginalized in the current wave of globalization.

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Figure 1: The elasticity of bilateral trade to distance (Evolution of $|\beta_t|$ under the standard and the augmented trade-barrier function). Notes: Equations are taken from table 1, columns 1 and 5.

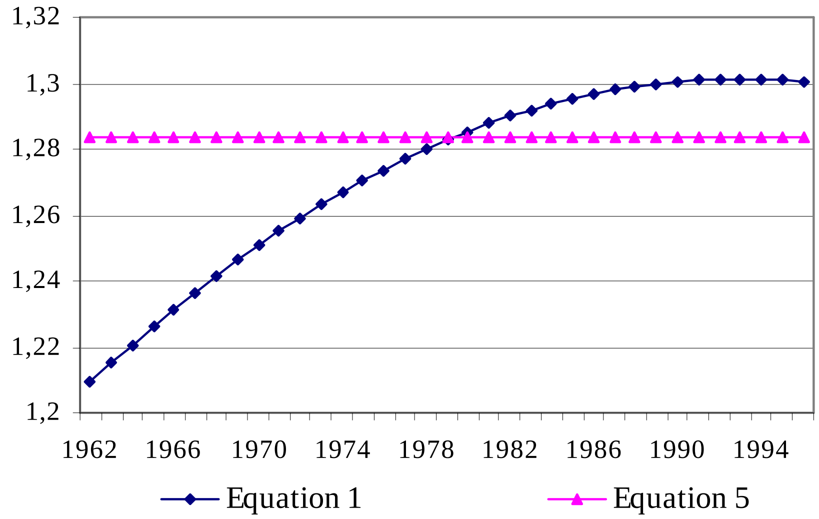


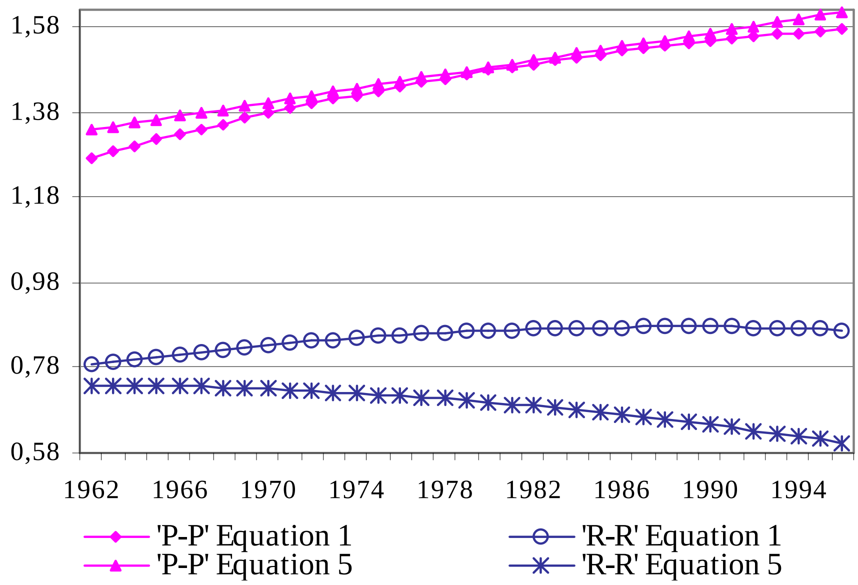
Table 1: Gravity panel estimates

	Eq 1	Eq 2	Eq 3	Eq 4	Eq 5
Y_{it}	0.876	0.883	0.881	0.909	0.958
	(43.66)	(47.43)	(44.79)	(51.30)	(50.74)
Y_{jt}	1.159	1.152	1.216	0.974	1.054
	(54.81)	(57.68)	(64.85)	(52.73)	(79.28)
N_{it}	-0.041	-0.011	-0.006	-0.064	-0.019
	(2.22)	(0.69)	(0.33)	(4.50)	(1.25)
N_{jt}	-0.198	-0.191	-0.233	-0.239	-0.160
	(10.80)	(11.11)	(13.74)	(13.74)	(12.76)
D_{ij}	-1.203	-1.215	-1.281	-1.180	-1.283
	(68.14)	(68.50)	(74.53)	(67.39)	(74.33)
L_{ij}	0.941	0.939	1.25	0.987	1.295
	(23.70)	(23.70)	(30.38)	(25.10)	(31.82)
E_i	-0.546	-0.533	-0.472	-0.471	-0.476
	(13.69)	(14.32)	(12.04)	(13.84)	(14.29)
E_j	-0.070	-0.081	-0.073	-0.260	-0.276
	(1.70)	(2.08)	(1.89)	(7.87)	(8.29)
RER_{ijt}	-0.0005	-0.0005	-0.0005	-0.0005	-0.0005
	(6.22)	(6.05)	(6.48)	(6.36)	(1.89)
t	-0.026	-0.024	-0.055	-0.025	-0.056
	(4.49)	(4.09)	(9.76)	(4.40)	(9.73)
$t.D_{ij}$	-0.00617	-0.0032	-0.00179	-0.00647	-0.00051
	(8.47)	(4.33)	(2.65)	(6.27)	(0.69)
$t^2.D_{ij}$	0.00010	0.00008	0.00010	0.0001	0.000005
	(14.63)	(9.15)	(17.49)	(16.16)	(0.45)
P_{Ft}		-0.097			-0.097
		(6.70)			(6.67)
K_{ijt}			0.263		0.272
			(20.98)		(21.91)
π_{jt}				-0.311	-0.214
				(14.54)	(10.39)
obs.	171998	171998	171998	171998	171998
R-sq	0.52	0.53	0.53	0.53	0.54
F	9163	8489	13205	10166	11808
	F(12,171985)	F(13,171984)	F(13,171984)	F(13,171984)	F(14,179356)
GLSvsHT	10622	9869	18194	7501	13859
	chi-2(12)	chi-2(13)	chi-2(13)	chi-2(13)	chi-2(15)

Table 2: Gravity panel estimates by group

	" P-P"		" R-R"	
	Eq1	Eq 5	Eq 1	Eq 5
Y_{it}	0.859	0.753	0.948	1.263
	(19.34)	(18.02)	(27.33)	(31.37)
Y_{jt}	0.981	0.951	1.357	1.255
	(20.97)	(28.67)	(31.34)	(41.11)
N_{it}	−0.116	0.038	−0.013	−0.245
	(3.32)	(1.23)	(0.35)	(6.40)
N_{jt}	−0.091	−0.177	−0.334	−0.312
	(2.50)	(6.26)	(7.56)	(9.94)
D_{ij}	−1.258	−1.330	−0.782	−0.739
	(38.06)	(40.21)	(34.62)	(32.75)
L_{ij}	0.834	1.054	0.487	0.934
	(15.58)	(19.64)	(5.45)	(10.57)
E_i	−0.769	−0.449	−0.333	−0.145
	(11.68)	(8.53)	(4.99)	(3.34)
E_j	−0.623	−1.003	−0.210	−0.003
	(8.59)	(15.78)	(3.39)	(0.06)
RER_{ijt}	−0.0005	−0.0005	−0.0007	−0.0007
	(3.46)	(3.66)	(5.52)	(5.31)
t	0.048	0.034	−0.0045	−0.030
	(4.51)	(3.17)	(0.64)	(4.28)
$t.D_{ij}$	−0.0145	−0.0082	−0.0068	0.0005
	(10.45)	(5.50)	(9.35)	(0.60)
$t^2.D_{ij}$	0.0002	0.0000	0.00012	0.00011
	(12.19)	(0.31)	(15.04)	(9.73)
P_{Ft}		−0.199		−0.015
		(6.72)		(0.78)
K_{ijt}		0.552		0.455
		(29.18)		(27.17)
π_{jt}		−0.429		−0.130
		(9.35)		(4.93)
obs.	57322	57332	57332	57332
R-sq.	0.47	0.48	0.55	0.57

Figure 2: The elasticity of bilateral trade to distance by group (Evolution of $|\beta_t|$ by group). Notes: Equations coefficients from table 2.



Appendices to
Has Distance Died? Evidence from a Panel Gravity Model
(not submitted for publication)
Jean-François Brun/Céline Carrère/Patrick Guillaumont/Jaime de Melo

Appendix A1: Data sources and data preparation

The database includes a potential of $586,950 = 130.129.35$ bilateral flows. With no missing data reported, trade flows are recorded for 29% of the potential transactions number which represent almost the whole world trade.

$\mathbf{M_{ijt}}$: Total bilateral imports by country i from country j at date t, UN-COMTRADE. This variable, in current US$, is divided by an index of the unit value of imports, taken from IFS, to obtain a real flow of trade. The original database does not contain any zero.

$\mathbf{Y_{i(j)t}}$:GDP of country i (j) at date t, in constant US$ 1995, CD-ROM WDI, World Bank 1999.

$\mathbf{N_{i(j)t}}$ **:** Total population of country i (j) at date t, CD-ROM WDI, World Bank 1999.

$\mathbf{D_{ij}}$:Distance measured in kilometers between the main city in country i and the main city in country j. Data for distance are taken from the software developed by the company CVN. Most of the time, the main city is the capital city, but for some countries the (or a) main economic city is considered. The distance calculated by the software is orthodromic, that is, it takes into account the sphericity of the earth. More precisely,'the distance between two points A and B is measured by the arc of the circle subtended by the chord [AB]' (see HAINRY, "Jeux Mathématiques et Logiques – Orthodromie et Loxodromie ").

$\mathbf{L_{ij}}$ **:** Dummy equal to one if i and j share a common land border, 0 otherwise.

$\mathbf{E_{i(j)}}$**:** Dummy equal to one if i (j) is a landlocked country, 0 otherwise.

$\mathbf{K_{ijt}}$ **:** Infrastructure index, built using 4 variables taken from the data base constructed by Canning (1996): number of kilometers of roads, of paved roads, of railways, and number of telephone sets/lines per capita. The first three variables are in ratio to the surface area (WB, 1999) to obtain a density. Each variable, thus obtained, is normalized to have a mean equal to one. An arithmetic average is then calculated over the four variables. As the database has for final year 1995, an extrapolation has been made to cover the year 1996.

$\mathbf{PF_t}$ **:** world oil price index is taken from International Financial Statistics (IMF). This variable has been divided by the index of the unit value of imports.

$\boldsymbol{\pi_{jt}}$: the ratio of primary export products to total export of the country j at date t. Data have been calculated from UN-COMTRADE.

$\mathbf{RER_{ijt}}$: Bilateral real exchange rate (RER) is computed as follow: $RER_{ijt} = (CPI_{jt})/(CPI_{it}).(NER_{it/\$t}/NER_{jt/\$t})$, where i is the importing country, j the exporting one, $NER_{it/\$t}$ is the nominal exchange rate for each currency against US$ (country i's currency value for 1 US$) at date t, and CPI_{it} the consumption price index for country i. Data are taken from the IFS database. If the CPI is not available, the GDP deflator is used instead. For each pair of countries, we specify the RER such as its mean over the period is zero.

Appendix A2: Derivations and estimation method

A2.1 Derivation of equation (1)

As in Deardorff (1998), we assume that each country i is specialized in a single good, and has a representative consumer maximizing a homothetic utility function:

$$U^i = \left(\sum_j b_j C_{ij}^{\left(\frac{\sigma-1}{\sigma}\right)} \right)^{\left(\frac{\sigma}{\sigma-1}\right)} \tag{A1}$$

where is the common elasticity of substitution between any pair of countries' products ($\sigma > 0$), and $b_j = b_i$ (i, j) guarantees symmetry and a single price for each product variety. Product differentiation is at the national level (rather than at the firm level as in the monopolistic competition version), and CES preferences (rather than Cobb-Douglas) implies that bilateral trade decreases with distance. Each consumer Maximization of (A1) subject to the budget constraint $Y_i = p_i x_i$ (with x_i the production of the destination country i and p_i the consumer price in i) gives:

$$C_{ij} = \frac{1}{p_i} b_j \left(\frac{p_i}{\overline{P}_j} \right)^{1-\sigma} Y_i \tag{A2}$$

where

$$\overline{P}_i = \left(\sum_j b_j p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{A3}$$

is the CES price aggregator in country i associated with the minimization of expenditures in the utility maximization problem. Assume that the relationship between the price in the country of origin j,p_j, and the country of destination i, p_i is given by :

$$p_i = \theta_i^I \theta_{ij}^D \theta_j^I p_j e_{ij} = p_j e_{ij} \theta_{ij} \tag{A4}$$

In (A4), $\theta_j^I(\theta_i^I)$ captures distance-independent transaction costs that impede trade in the country of origin (destination) such as the quality of infrastructure, θ_{ij}^D represents transaction costs dependent on distance and e_{ij} is the nominal bilateral exchange rate.

To get the standard gravity-based model, assume balanced trade and let $\gamma_j = Y_j/Y_W$ be the share of country j in world income, Y_W. Expenditures of all countries i on the good produced in j are $\sum_i p_i C_{ij}$. Then, $Y_j = \sum_i p_i C_{ij}$ and substituting the value of C_{ij} from (A2) into this expression gives the following expression for b_j:

$$b_j = \gamma_j \left(\sum_i \gamma_i \left(\frac{p_i}{\overline{P}_i} \right)^{1-\sigma} \right)^{-1} \tag{A5}$$

Substituting (A5) into (A2), the volume of imports of i from j is given by:

$$M_{ij} = \frac{Y_i Y_j}{Y_W} \left[\frac{\frac{(p_i)^{-\sigma}}{\left(\overline{P}_i\right)^{1-\sigma}}}{\sum_h \left(\frac{p_i}{\overline{P}_h}\right)^{1-\sigma}} \right] = \frac{Y_i Y_j}{Y_W} \theta_{ij}^{-\sigma} e_{ij}^{-\sigma} \left[\frac{\frac{(p_j)^{-\sigma}}{\left(\overline{P}_i\right)^{1-\sigma}}}{\sum_h \left(\frac{p_i}{\overline{P}_h}\right)^{1-\sigma}} \right] \tag{A6}$$

with $i, j, h = 1, ..., n$

Noting that the denominator is the expenditure-share-weighted average world price, $\overline{\overline{P}}$, one gets the familiar gravity-type equation:

$$M_{ij} = \frac{Y_i Y_j}{Y_W} \theta_{ij}^{-\sigma} e_{ij}^{-\sigma} \left[\frac{\frac{(p_j)^{-\sigma}}{\left(\overline{P}_i\right)^{1-\sigma}}}{\left(\overline{\overline{P}}\right)^{1-\sigma}} \right] \qquad i, j, h = 1, ..., n$$

The intensity of trade between two countries is a function of their respective size and that it is a decreasing function of the extent of barriers to trade θ_{ij}.

Choose units so that $p_i = p_j = p_h = 1$ and $e_{ij} = 1$. Then, as shown by Deardorff, (given by A3) becomes an index of country i's barriers-to-trade factor as an importer. Using Deardorff's notation, the average barrier-to-trade from suppliers, δ_j^S , is given by:

$$\delta_j^S = \left(\sum_j b_j \left(\theta_i^I \theta_{ij}^D \theta_j^I\right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{A7}$$

The barriers-to-trade factor for supplier j in country i, ρ_{ij}, is given by:

$$\rho_{ij} = \frac{\theta_i^I \theta_{ij}^D \theta_j^I}{\delta_j^S} \tag{A8}$$

Letting $\theta_i^I = \theta_j^I = 1$ in (A8) gives expression (20) in Deardorff (1998). Substituting (A7) and (A8) into (A6) gives expression:

$$M_{ij} = \frac{Y_i Y_j}{Y_W} \theta_{ij}^{-\sigma} \left[\frac{\left(\delta_j^S\right)^{\sigma-1}}{\sum_h \gamma_h \rho_{jh}^{1-\sigma}} \right] \qquad i, j, h = 1, ..., n \tag{A9}$$

A2.2 Decomposition of the elasticity of distance to transport cost ($\partial\gamma_t/\mathbf{t}$)

From (9), (10)and (11) it follows that:

$$\theta_{ijt} = f(K_{ijt}; \pi_{jt}) + g(D_{ij}.PF_t; D_{ij}.\pi_{jt}) \tag{A10}$$

and since

$$\gamma_t \equiv (\partial\theta_{ijt}/\theta_{ijt})/(\partial D_{ij}/D_{ij}) \equiv (\partial\theta_{ijt}/\partial D_{ij})/(\theta_{ijt}/D_{ij})$$

we have:

$$\gamma_t = \frac{g(D_{ij}.PF_t; D_{ij}.\pi_{jt})}{f(K_{ijt}; \pi_{jt}) + g(D_{ij}.PF_t; D_{ij}.\pi_{jt})} \tag{A11}$$

Hence,

$$\frac{\partial\gamma_t}{\partial t} = \frac{\left(\frac{\partial g(.)}{\partial PF_t}.\frac{\partial PF_t}{\partial t}\right) + \left(\frac{\partial g(.)}{\partial \pi_{jt}}.\frac{\partial \pi_{jt}}{\partial t}\right).\theta_{ijt}}{\theta_{ijt}^2}$$

$$-\frac{g(.)\left[\left(\frac{\partial f(.)}{\partial K_{ijt}}.\frac{\partial K_{ijt}}{\partial t}\right) + \left(\frac{\partial f(.)}{\partial \pi_{jt}}.\frac{\partial \pi_{jt}}{\partial t}\right)\right]}{\theta_{ijt}^2}$$

$$-\frac{g(.)\left[\left(\frac{\partial g(.)}{\partial PF_t}.\frac{\partial PF_t}{\partial t}\right) + \left(\frac{\partial g(.)}{\partial \pi_{jt}}.\frac{\partial \pi_{jt}}{\partial t}\right)\right]}{\theta_{ijt}^2} \tag{A12}$$

with $\theta_{ijt}^2 > 0, \theta_{ijt} > 0, g(.) > 0$. The sign of $\partial\gamma_t/\partial t$depends on the sign of the numerator, which can be redefined as:

$$\frac{\partial\gamma_t}{\partial t} = \underbrace{\left[\left(\frac{\partial g(.)}{\partial PF_t}.\frac{\partial PF_t}{\partial t}\right)(\theta_{ijt} - g(.))\right]}_{>0} + \underbrace{\left[-g(.)\left(\frac{\partial f(.)}{\partial K_{ijt}}.\frac{\partial K_{ijt}}{\partial t}\right)\right]}_{>0}$$

$$+ \underbrace{\left[\left(\frac{\partial g(.)}{\partial \pi_{jt}}.\frac{\partial \pi_{jt}}{\partial t}\right)(\theta_{ijt} - g(.))\right]}_{<0} + \underbrace{\left[-g(.)\left(\frac{\partial f(.)}{\partial \pi_{jt}}.\frac{\partial \pi_{jt}}{\partial t}\right)\right]}_{<0} \quad \text{(A13)}$$

with $(\theta_{ijt} - g(.)) = f(.) \geqslant 0$

In (A12) and (A13), we make the following assumptions: $\partial g(.)/\partial PF_t > 0$ and $\partial g(.)/\partial \pi_{jt} > 0$ $\partial f(.)/\partial K_{ijt} < 0$ and $\partial f(.)/\partial \pi_{jt} < 0$

Over the period 1962-1996 (see appendix A3), the trend of the real price of oil has been increasing and the quality of infrastructure improving. So $\partial PF_t/\partial t > 0$ and $\partial K_{ijt}/\partial t > 0$, moreover, on average, $\partial \pi_{jt}/\partial t < 0$.

A2.3 Estimation method

Write the model as:

$$M_{ijt} = X_{ijt}\varphi + Z_{ij}\delta + u_{ijt} \; with \; u_{ijt} = \mu_{ij} + \nu_{ijt} \quad \text{(A14)}$$

where: $X = k$ variables variant overtime, $Z = g$ variables time invariant.

Assume that X_1 (dimension k_1) are exogenous variables, and X_2 (dimension $k - k_1$) are endogenous variables (i.e. variables correlated with the random specific effects -here Y_{it} and Y_{jt}).

Then (A14) can be estimated using as instruments $[QX_1, QX_2, PX_1, Z]$ (see Breusch, Mizon and Schmidt 1989). The instruments are the variables X_1, both as individual means and as deviations from individual means, the variables X_2 as deviations from individual means only and the variables Z. The instruments are then taken within the model.

However, the resulting estimator is consistent but not efficient, as it is not corrected for heteroskedasticity and serial correlation. We follow Hausman and Taylor (1981), and use the first round of estimates to compute the variance of the specific effect and the variance of the error term. The instrumental variable estimator is then applied to the following transformed equation:

$$[M_{ijt}-(1-\theta)M_{ij.}]=[X_{ijt}-(1-\theta)X_{ij.}]\varphi+[\theta Z_{ij}]\delta+[\theta\mu_{ij}+[\nu_{ijt}-(1-\theta)\nu_{ij.}]] \tag{A15}$$

where $\theta=\left(\frac{\sigma_\nu^2}{T\sigma_\mu^2+\sigma_\nu^2}\right)^{1/2}$ and $M_{ij.}=\frac{1}{T}\sum_t M_{ijt}$

To compare the Hausman Taylor estimator, β_{HT}, and the GLS estimator, β_{GLS}, we use a test proposed by Guillotin and Sevestre (1994). The Hausman statistic is based on:

$$[\beta_{GLS}-\beta_{HT}][var(\beta_{HT})-var(\beta_{GLS})]^{-1}-1[\beta_{GLS}-\beta_{HT}]' \tag{A16}$$

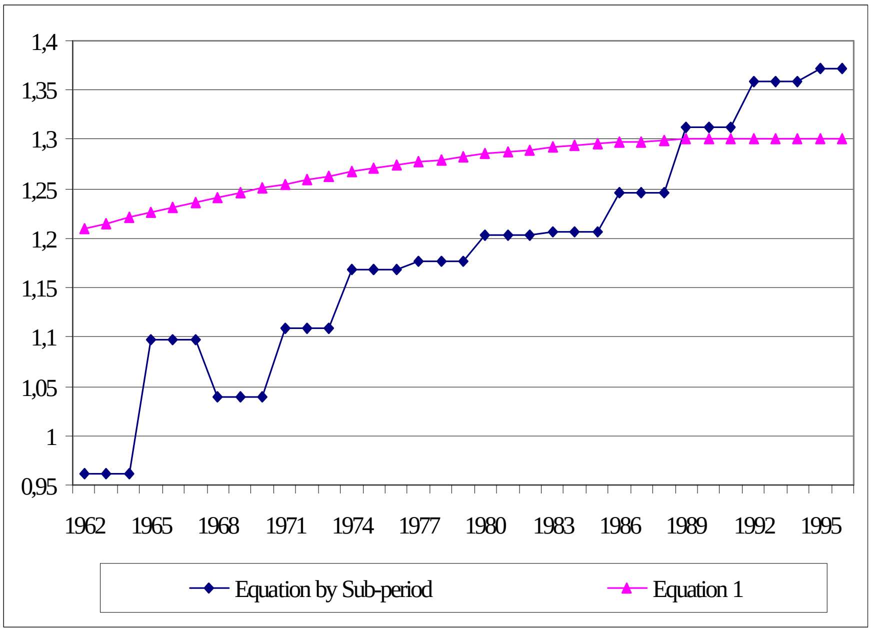
Under the null, this test statistic is distributed as a Chi-square with degrees of freedom equal to the dimension of the vector β_{GLS}, constant excluded. If the calculated statistic is greater than the critical value, then the null is rejected and the Hausman-Taylor estimator is preferred to the GLS estimator.

Appendix A3: description of P_{Ft}, K_{ijt} and π_{jt} over 1962-1996.

Table notes:
a) Compound growth g=[(X_{1996}/X_{1962})$^{1/35}$-1]*100.
K_{ijt}= Infrastructure index (unweighted average).
PF_t = Relative price of oil (1995=100).
π_{jt} = Share of primary products in total exports of country j.

Years	PF_t	K_{ijt}			π_{jt}		
		Total	'P-P'	'R-R'	Total	'P-P'	'R-R'
1962	60,0	0,86	0,42	1,04	69,2	82,3	64,3
1963	59,7	0,85	0,37	0,99	68,4	84,4	65,6
1964	58,5	0,89	0,43	1,09	67,8	82,7	63,2
1965	58,0	0,88	0,37	1,10	67,3	81,1	63,4
1966	57,0	0,87	0,33	1,12	66,9	81,8	59,1
1967	57,2	0,88	0,36	1,16	65,8	80,5	59,2
1968	57,8	0,85	0,33	1,14	66,9	83,0	58,8
1969	56,4	0,85	0,34	1,14	65,6	82,0	56,9
1970	55,9	0,82	0,29	1,12	65,9	81,7	58,9
1971	64,5	0,85	0,30	1,15	64,7	81,0	57,4
1972	64,8	0,84	0,29	1,16	63,8	79,3	57,1
1973	59,0	0,85	0,28	1,21	63,8	78,7	56,8
1974	150,1	0,83	0,28	1,19	64,7	79,0	57,0
1975	129,7	0,86	0,30	1,24	63,5	77,1	55,8
1976	143,2	0,91	0,32	1,33	62,3	75,1	55,1
1977	142,5	0,94	0,32	1,37	62,5	76,2	54,4
1978	131,8	0,98	0,35	1,43	60,1	73,5	51,7
1979	251,0	0,96	0,32	1,39	62,9	76,2	55,0
1980	249,3	0,98	0,37	1,43	62,4	74,2	54,2
1981	241,8	0,99	0,38	1,43	62,6	74,5	54,2
1982	233,9	1,06	0,41	1,53	60,4	72,4	51,0
1983	223,0	1,09	0,42	1,59	60,0	77,6	49,8
1984	219,6	1,18	0,49	1,69	54,6	66,0	46,7
1985	214,9	1,22	0,51	1,76	54,2	67,3	45,5
1986	108,3	1,18	0,46	1,72	50,9	64,3	41,2
1987	127,6	1,25	0,51	1,80	49,5	61,2	41,1
1988	98,8	1,33	0,56	1,93	47,2	56,8	40,9
1989	118,3	1,30	0,52	1,89	46,5	55,8	40,5
1990	140,1	1,31	0,50	1,94	47,5	57,8	40,4
1991	119,9	1,26	0,52	1,84	47,9	57,9	41,1
1992	116,9	1,30	0,54	1,92	45,4	52,9	40,1
1993	109,5	1,33	0,55	1,98	44,5	52,0	39,0
1994	101,2	1,46	0,57	2,21	43,4	51,1	37,5
1995	100,0	1,53	0,61	2,30	44,9	55,8	36,7
1996	118,5	1,59	0,62	2,45	43,1	53,4	36,3
Growth a) (%)	1,96	1,77	1,12	2,48	-1,34	-1,23	-1,62

Appendix A4: Evolution of $|\beta_t|$ by sub-period of three years.



Notes:

- Equation 1: column 1 in table 1.
- Equation by sub-period:

$\mathrm{M}_{ijt} = \alpha_0(\mathrm{Y}_{it})^{\alpha_1}.(\mathrm{Y}_{jt})^{\alpha_2}.(\mathrm{Nit})^{\alpha_3}.(\mathrm{Njt})^{\alpha_4}.(\mathrm{Dij})^{\beta_1}.\mathrm{e}^{\alpha_5 L_{ij}}\mathrm{e}^{\alpha_6 E_i}.\mathrm{e}^{\alpha_7 E_j}.\mu_{ij}.\nu_{ijt}$
is estimated in log. Figure plots the $|\beta_1|$ value obtained for each sub-period.