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North, South and Distance in the Gravity Model

J. MELITZ[1]

[1] CREST-INSEE, University of Strathclyde, U. K. and CEPR.

Abstract

It is generally assumed that distance in the gravity model strictly reflects frictions impeding bilateral trade. However, distances North-South could also reflect differences in factor endowment that provide opportunities for profitable trade. This paper investigates the hypothesis that if we control for distance in the ordinary sense, differences North-South promote international trade. The hypothesis receives ample support. Moreover, the significance of differences North-South survives a battery of robustness tests, concerning period, distinctions between differences in latitude North-North, North-South and South-South, and controls for other measures of differences in factor endowment, such as differences in per capita output and differences in average temperature, rainfall, and seasonal range in temperature. The impact of differences North-South on bilateral trade has also been falling. This decline, in turn, might be partly responsible for the weakening of the influence of distance that has been occurring since World War II. This last hypothesis receives confirmation as well. Finally, the paper studies two country-specific aspects of distance: internal distance and remoteness. It does so by examining the impact of both on the country fixed effects themselves: that is, those that emerged earlier. Internal distance turns out to have a far greater impact than remoteness – by an order of ten.

Journal of Economic Literature classification: F10, F33

Keywords : gravity, bilateral trade, distance, remoteness, comparative advantage, North-South trade.

Résumé

On suppose généralement dans le modèle de gravité que la distance reflète strictement des frictions qui nuisent aux échanges bilatéraux. Néanmoins, les distances Nord-Sud pourraient aussi refléter des différences de dotation offrant l'occasion d'échanges rentables. Ce papier examine l'hypothèse que si on contrôle pour la distance dans le sens ordinaire, les différences Nord-Sud encouragent le commerce international. Cette hypothèse est fort confortée. D'ailleurs, la signifiance des différences Nord-Sud résiste à toute une file de tests de robustesse, concernant période, distinctions entre différences de latitude Nord-Nord, Nord-Sud et Sud-Sud, et des contrôles pour autres mesures de différences de dotation, tels des différences de production par tête et de moyennes de température, précipitation, et variation saisonnière de température. L'impact des échanges bilatéraux connaît aussi une décroissance. Celle-ci, à son tour, pourrait alors expliquer partiellement la baisse de l'influence de la distance depuis la deuxième guerre mondiale. Cette dernière hypothèse, elle aussi, est confirmée. Enfin, le papier examine deux aspects de la distance qui dépendent strictement du pays particulier : la distance interne et l'éloignement. Ce dernier test consiste à étudier les effets fixes par pays eux-mêmes : c'est-à-dire ceux qui se sont révélés auparavant. Il s'avère que l'impact de la distance interne est notamment plus important que celui de l'éloignement – par un facteur de dix.

Journal of Economic Literature classification: F10, F33

Mot-clefs : gravité, échange bilatéral, distance, éloignement, avantage comparatif, commerce Nord-Sud.

The significance of distance in explaining bilateral trade is perhaps the most remarkable success of the gravity model. The negative effect of distance on trade is intuitive: it reflects transportation costs. Yet in some respects this negative effect is surprising. Consider distance North-South. With greater distance in this direction, geography changes, and the changes might lead to opportunities for profitable trade. The latitude of a country affects the length of its days, its sunlight, its temperatures and seasons, and it alters not only its plant and animal life and the yield of its land and waters, but its required insulation and its optimal production techniques. Diamond's (1997) fascinating history of mankind strongly suggests that production opportunities can often be reproduced through selective planting, breeding, tooling and exertion at any given latitude on earth, but that such efforts become increasingly futile as we move North or South. If this is right, factor endowments change with movements North-South and the basis for Ricardian trade increases. Thus, as long as we control for great-circle distances (and therefore transportation costs), greater distance along the North-South axis should increase trade. On the other hand, if we do not control for differences in latitudes between countries, the influence of distance on bilateral trade could work in either direction. Transportation costs will tend to diminish trade, but differences in production opportunities will go the other way.

Independently, on theoretical grounds, we should always control for the country-specific aspects of distance if we are to expect distance between countries – bilateral distance – to have a uniform effect on bilateral trade. In principle, the same distance between a country pair will have different implications depending on whether both countries have many near-by neighbors or few. It will also matter whether they are small, so that foreigners are possibly close everywhere, or whether they are big, so that foreigners must be far away from many parts of the interior (cf. Deardorff (1998) and Anderson and van Wincoop (2004), pp. 713-715). There is then reason to include remoteness and internal distance as joint variables together with bilateral distance. But studies of the gravity model that include either or both have tended to ignore country fixed effects in the past (for example, Frankel (1997), Wolf (1997), Helliwell (1998), Nitsch (2000)). This is understandable since remoteness and internal distance will be highly or perfectly correlated with country fixed effects. (They must be perfectly so unless there are time-varying weights serving in their construction.) However, recent work on the gravity model stresses the importance of controlling for all border effects with third countries or multilateral trade resistance (Anderson and van Wincoop (2003)). Without such controls, the estimates may be unreliable. On this view, all previous estimates of remoteness and internal distance are in question. Besides introducing the variable North-South, another ambition of this paper is to confront this issue. I propose to do so by examining the influence of remoteness and internal distance on the country fixed effects themselves.

A major conclusion of the study is that distance does indeed increase trade along the North-South dimension. If we control for distance in the ordinary sense, differences in latitudes between countries promote international trade. The impact of differences in latitudes is about 13 percent of that of ordinary distance but the statistical significance of the impact is extremely high. Moreover, the significance of differences in latitudes survives a battery of robustness tests, concerning period, distinctions between differences in latitude North-North, North-South and South-South, and controls for other measures of differences in factor endowment, such as differences in per capita output and differences in climate. Therefore, differences in latitude emerge as a basic reflection of differences in production opportunities in the gravity framework.

Very significantly, the impact of differences in latitude North-South has also been declining. This decline could then contribute to the rise in the negative influence of distance on bilateral trade in recent decades. Disdier and Head (2004) confirm this rise in influence in a recent, sophisticated meta-analysis of 78 studies of distance. Compare Leamer and Levinsohn (1995), Eichengreen and Irwin (1998), Carrère and Schiff (2004) and Berthelon and Freund (2004). The rise has puzzled many. There have been a variety of suggested explanations: for example, Frankel (1997), p. 74, Coe et al. (2002), and Anderson and van Wincoop (2004), p. 731. All the explanations thus far suppose that distance reflects strictly trade frictions. But if distance is partly an inducement to trade, then a weakening of this inducement could account for the rising negative effect of distance. In fact, trade in differentiated products has increased relative to trade based on comparative advantage in recent decades. During my study period, 1970-95, trade in agricultural and mining products grew annually less than half as much as trade in manufacturing on average (see World Trade Organization (2004), Chart II.2). If the sort of trade that benefits from distance North-South has lost ground, then distance must increasingly reflect trade frictions alone rather than a mix of trade frictions and trade opportunities. A rise in the negative coefficient of distance follows.

With respect to the country-specific considerations, remoteness and internal distance, my results show that internal distance is a significant inhibiting influence on foreign trade while remoteness is less so. In fact, remoteness does not affect trade at all for the 20 or so least remote countries, which are essentially European. Even outside of these countries, remoteness only reduces trade by about 2 percent on average whereas internal distance reduces trade about 10 times more. Thus, another fundamental result of this study is that internal distance is far more important than remoteness.

The next section provides the theoretical framework and the econometric specification. The following section, II, discusses the test results regarding differences North-South. Next, section III concerns the influence of remoteness and internal distance. A short concluding section follows.

I. Theory and Test Specification

The literature provides two bases for foreign trade. According to one, trade results from differences in factor endowments. According to the other, it is driven by a combination of consumer tastes for variety and increasing returns. In both cases, transportation costs limit trade. The gravity model introduces consumer tastes for a variety of goods together with countries that produce different goods. This opens the way for both forms of trade. Admittedly, the gravity literature tends to focus on trade in differentiated products under increasing returns. But even in the examples of allowance for Heckscher-Ohlin considerations and Ricardian trade (e.g., Bergstrand (1989, 1990), Eaton and Kortum (2002), Evenett and Keller (2002)), never is there any hint that distance may reflect the ability of countries to trade on the basis of comparative advantage rather than specialization alone. The assumption is always that distance reflects strictly frictions and transportation costs.

I will use a simple form of the gravity model in my reasoning below. Suppose we begin with the standard case where all countries specialize in the production of separate goods or separate varieties, and utility functions are identical, homothetic, and CES everywhere. Assume, in addition, that trade frictions raise the price to the importer above the exporter's price by the same percentage, regardless whether the goods move one way or the other. Under these assumptions, Anderson and van Wincoop (2003) show that the following gravity equation obtains:

$$(1)\ T_{ij} = \frac{Y_i Y_j}{Y^W}\left(\frac{t_{ij}}{P_i P_j}\right)^{1-\sigma}$$

T_{ij} is the trade flow in either direction between countries i and j, Y_i and Y_j are the respective incomes of the two countries, Y^W is world income, σ is the elasticity of substitution between different goods, t_{ij} is $1+x_{ij}$ where x_{ij} stands for the percentage of the costs attributable to *foreign* trade frictions in relation to the export price p (regardless whether this price (fob) is p_i or p_j), and P_i and P_j are the respective Dixit-Stiglitz consumer-based price levels in the two countries. In the case of P_j:

$$(2)\ P_j = \left[\sum_i (\beta_i p_i t_{ij})^{1-\sigma}\right]^{1/(1-\sigma)}$$

where the summation sign embraces all i prices inclusive of p_j (in which case, exceptionally, $t_{jj} = 1$ and $p_j t_{jj} = p_j$) and β_i is the distribution parameter of the utility function (for good i or the varieties coming from country i). The corresponding equation holds for P_i. Evidently, σ must be greater than one, as empirical work tells us is predominantly the case, in order for there to be a negative effect of t_{ij} on trade. Since the derivation itself requires $t_{ij} = t_{ji}$, balanced bilateral trade necessarily follows in this form of the model. But that is of no importance, as differences between exports and imports are of no interest here (as is often the case) and the concern is strictly with total bilateral trade.

In common with much of the gravity literature, I will interpret t_{ij} as a set of controls for all possible aids and impediments to bilateral trade. Accordingly, t_{ij} will then embrace differences in latitude North-South and other possible reflections of differences in factor endowments as well as the usual gravity variables: distance, ex-colonial attachments, a common language, and so forth – the usual suspects.

More precisely, let the t_{ij} term in equation (1) be:

$$(3)\ \ t_{ij} = \prod_{k=1}^{k=m} u_{ij,k}^{\gamma_k} \times \exp\left(\sum_{k=1}^{k=n} \eta_k v_{ij,k} \right)$$

where the u terms are continuous variables, and the v ones are percentage values or 0-1 dummies. As regards P_iP_j, there are two alternative empirical specifications:

$$(4)\ \ P_iP_j = \prod_{k=1}^{k=r} \left(w_{i,k} w_{j,k} \right)^{\tau_k} \times \exp\left(\sum_{k=1}^{k=s} \gamma_k z_{i,k} z_{j,k} \right) \text{ or}$$

$$(5)\ \ P_iP_j = \exp\left(\sum_{k=1}^{k=c} \delta_k C_k \right) \qquad i, j \in k$$

Equation (4) spells out all of the influences on P_i and P_j individually, while equation (5) collects all of them together under the cover of a separate dummy C per country (with c countries). In sync with the distinction between u and v in equation (3), the w terms in equation (4) are continuous while the z ones are percentages or dummies. As the logic requires (and the notation signifies), the w and z variables are country-specific.

The use of country fixed effects is a way of encompassing all the country-specific elements, observed and unobserved. This is an attractive feature of the specification. As a result, only equation (5) will serve in estimating T_{ij}. The estimated form of the gravity model will then be:

$$\begin{aligned}(6)\ \log T_{ij} = {} & \text{constant} + \alpha \log (Y_iY_j) \\ & + (1-\sigma)\ \gamma_1 \log u_{ij,1} \ldots + (1-\sigma)\ \gamma_m \log u_{ij,m} + (1-\sigma)\ \eta_1 v_{ij,1} \ldots + (1-\sigma)\ \eta_n v_{ij,n} \\ & + (\sigma-1)\ \delta_i C_i + (\sigma-1)\ \delta_j C_j \ldots + (\sigma-1)\ \delta_c C_c + e_{ij}\end{aligned}$$

The constant here embraces Y^W. The coefficient α of the log (Y_iY_j) term (which can only be estimated in the event of some temporal dimension) should evidently equal one. The country dummies C_i and C_j equal one while the rest of the C_k dummies ($k \neq i, j$) are zero. The term e_{ij} is white noise associated with the dependent variable, bilateral trade.

The precise u and v terms in the estimates will include, if no others:

log $u_{ij,1}$, log $u_{ij,2}$ = log of distance, log of difference North-South.

$v_{ij,1}, \ldots, v_{ij,n}$ = adjacency, common language, currency union, political union, free trade area, ex-colonial relationship, ex-common colonizer.

The v variables in this listing refer to indices of political association that often appear in gravity equations. In particular, Frankel and Rose (2002) successfully use all of them. These dummy variables notably provide some reflection of protectionism, which is not otherwise taken into account. There exist detailed indices of trade protection, but these are available only for a much narrower sample of countries than those that will serve below.

At the next stage of investigation, the focus shifts on the fixed effects in the estimates of equation (6). The following w and z terms of equation (4) then enter:

log $w_{i,1}$,…, log $w_{i,r}$ = log of average output, log of average population, log of remoteness, log of internal distance.

$z_{i,1}$, $z_{i,2}$ = landlocked, membership in ex-Soviet Union.

Y_iY_j was already mentioned as present in equation (6); but it can only reflect variations in output over time there. However, regardless of such variations, countries with larger output trade more with everybody, including foreigners. Hence, average output should enter separately as an influence on the country fixed effects. Average population should similarly enter but for totally different reasons. The more people there are at home, the wider the opportunities to trade domestically and therefore without bearing the costs of foreign trade. On this ground, the variable should have a negative impact on bilateral trade (compare Frankel and Romer (1999)). True, population might have been included earlier in equation (6) along with output since it varies over time just as output does. However, population is much more sluggish than output and it does not emerge as significant – not in my data set – when country fixed effects are present.

As regards the country fixed effects, remoteness and internal distance are the variables of central interest. Both variables increase multilateral trade resistance and therefore pull in favor of home trade and away from trade with foreigners in general. Remote countries have fewer good alternatives to trading at home than countries with many close neighbors since foreigners are further away. Large countries, or ones that sprawl over wide surfaces, basically face a comparable situation. Because of large internal distances, the people in those countries find foreigners to be further away than do those who live in small countries (all the more so if we control for remoteness). As a clear manifestation, large countries tend to be less open.[1] In regard to the dummy for the members of the ex-Soviet Union, trade outside the Soviet bloc was notoriously small under this political arrangement.

All of the data concerning the listed variables except for language and distance come from Frankel and Rose (2002) and are described in their appendix. Their data set covers six separate years at five-year intervals, starting with 1970 and ending in 1995. There are no zeros for trade. Roughly 31,000 observations from their set relating to 157 countries enter in the subsequent tests. I am indebted to Rose for making his data public on his website. With regard to language, I use a series that I constructed before, which takes into account the ability to communicate directly *as well as* status as an official language (Melitz (2005)). This series varies between zero and one and yields much better results than Frankel and Rose's (a 0-1 series that strictly concerns status as an official language). The only other deviation from Frankel and Rose regarding data that deserves mention at once is that I will consider all departments and territories of a country as automatically belonging to a free trade zone in the mother country. Thus, my dummies for a common country and free trade area are mutually exclusive.

II. Distance North-South

The usual measure of distance in the gravity literature is the great-circle distance or "as the crow flies." In measuring distance, sometimes authors locate countries at their geographical center, sometimes at their capital, sometimes at their most populous city. Experience shows that in studies that cover a world sample of countries, like this one, it does not matter.[2] Frankel and Rose use the CIA *Country factbook* to locate countries, and therefore

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[1] There is an important section of the gravity literature, stemming from Wei (1996), that focuses on the impact of internal distance on internal trade rather than, as I do here, its influence on external trade. See Wolf (1997, 2000), Helliwell (1998, chapter 3), Helliwell and Verdier (2001), and Nitsch (2000, 2001).

[2] Compare Disdier and Head (2004), Frankel (1997), pp. 70-73, and Rose (2000). It is not necessarily clear that the measure of bilateral distance even matters much in studies of regions of the world or sub-continents and even individual countries. Wolf (1997) and Nitsch (2001) find no striking differences resulting from different measures of distance in respective studies of interstate trade in the U.S. and inter-city trade in West Germany. By contrast, Helliwell and Verdier (2001) emphasize the importance of the measure of distance in a study of Canada.

implicitly place them at their geographical center. I will locate them at their most populous city. But the results with Frankel and Rose's measure are basically identical.

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(7) $\log T_{ij} = 1.06 \log Y_iY_j - 1.25 \log D + .44\ \text{Border} + .95\ \text{Lang} + .91\ \text{CU} + .62\ \text{ComC}$
(28) (–46) (3.4) (13) (4.9) (1.67)

$+ .32\ \text{FTA} + 1.61\ \text{Excol} + .58\ \text{Comcol}$ Year and country fixed effects
(2.56) (13) (7.3)

$R^2 = .73$ RMSE = 1.73 N = 31,001 Student t in parentheses
Correction of standard errors for clustering by country pair

D = distance Border = common border Lang = common language
CU= currency union ComC = common country FTA = free trade area
Excol = ex-colonial relationship Comcol = Ex-common-colonizer

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Equation (7) above displays the estimate of equation (6) when the North-South variable is absent, as is usually the case. The dependent variable is bilateral trade measured as the average of imports and exports (nominal imports plus exports in dollars deflated by the U.S. GDP chain price index and divided by two). The test includes fixed effects for the six years in the study (one of which then goes into the constant term) as well as for the individual countries. The estimates for these variables are not reported. The standard errors are robust and follow correction for clustering by country pair. As can be seen, the results are of the familiar sort with the right signs and mostly high precision of the estimates. The hypothesis of unitary elasticity of influence of output is notably confirmed. It would indeed make virtually no difference if unitary elasticity were imposed, as I have verified, and the possible endogeneity of output therefore is not an issue. Common Language also comes out to be far more important than is typical with my measure. The only variable that enters significantly below the 1 percent confidence level is Common Country (for which there are the least number of observations, only 47). The estimate of –1.25 for distance is within the usual range of –0.9 to –1.5, as reported in the recent survey by Overman, Redding and Venables (2003). It is also not far from Disdier and Head's "preferred estimate" of –1.11 in their very useful meta-analysis.

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(8) $\log T_{ij} = 1.06 \log Y_iY_j - 1.38 \log D + .19 \log \text{No-So} + .53\ \text{Border} + .9\ \text{Lang} + .92\ \text{CU}$

(28) (–46) (9.4) (4.2) (12) (4.9)

+.67 ComC + .37 FTA + 1.56 Excol + .64 Comcol Year and country fixed effects
(1.83) (3.04) (13) (8)

R^2 = .73 RMSE = 1.72 N = 31,001 Student t in parentheses
Correction of standard errors for clustering by country pair

D = distance Border = common border Lang = common language
CU= currency union ComC = common country FTA = free trade area
Excol = ex-colonial relationship Comcol = Ex-common-colonizer

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Equation (8) next shows the result of introducing the difference North-South between country pairs. Let lat1 and lat2 stand for the respective latitudes of country 1 and country 2 in a trading pair with Northern latitudes positive and Southern ones negative. The North-South difference is then |lat1 – lat2|. As seen, this influence enters positively, in accordance with the hypothesis, with a coefficient of .19 and a Student t of 9.4. Following the inclusion of North-South, the negative influence of the great-circle distance also goes up. This is logical, since the earlier estimate of the impact of distance emerges as the outcome of two opposite forces, one of which works toward a positive sign. Therefore, the negative effect should be lower. More specifically, based on equation (8), we might infer a coefficient of distance in equation (7) of around –1.19 (–1.38 +.19). The actual estimate is –1.25. The impact of a common border also comes out more sharply in equation (8) than before. This too is logical: once the role of distance is more properly estimated, so should the role of a common border. As we can see, when we go from equation (7) to equation (8) the coefficient of a common border rises by about 20 percent and there is a corresponding rise in the Student t with no change at all in the standard error.

A series of robustness tests follows. Most of the observations in the study relate to trade in the Northern hemisphere. To be precise, of the 31,001 observations that enter in equation (8), 20,301 concern trade in the North, 9,540 trade in the South, and 1,160 trade between the two hemispheres. Northern behavior is then dominant. Is this responsible for the results? With this issue in mind, I divided up North-South into North-North, North-South, and South-South. The first column of Table 1 shows the outcome. The coefficients of all three parts of the series are highly significant and reasonably alike.

Countries at similar latitudes in both hemispheres have similar climates. Thus, another concern would be that the relevant variable is not really North-South, |lat1 – lat2|, but the difference in latitude, | |lat1| – |lat2| |. Upon reflection, Difference in Latitude is identical to North-South in North-North and South-South trade but differs in trade between the two hemispheres where the difference is radical. In the case of trade between Argentina and Greece, for example, the Difference in Latitude is about 3 degrees, while the difference North-South is around 72 degrees. Since cross-hemispheric trade forms less than 3 percent of the total observations and, as we have seen, North-South works well without any sub-divisions whatever, we would expect Difference in Latitude to give reasonable results when included by itself. This is precisely what happens, as column 2 reveals (though Difference in Latitude does bear a lower coefficient than North-South in equation (8)). However, once we add North-South to the estimate, the significance of Difference in Latitude totally disappears (column 3). Thus, the importance of North-South does not seem to stem merely from climate. The opposition of the seasons and other differences between the two hemispheres – possibly related to currents, topography, ratios of land to water – evidently matter too. More support will follow shortly.

Column 4 of Table 1 next investigates the eminent hypothesis that differences in per capita output between countries reflect differences in capital-labor ratios (see Helpman (1981), Krugman (1981), Frankel (1997, pp. 60-61), and with close bearing, Bergstrand (1989, 1990)). On this view, differences in per capita output admit considerations of Heckscher-Ohlin. In order to measure these per capita differences, I use 1985 values for population and output. The use of in-sample average values instead would have yielded figures for per capita output that pertain to different time periods for different countries. This explains my choice. About 2,000 observations (out of 31,000) drop out because of missing output data for some countries in 1985. As seen in column 4, the difference in per capita output (in logs) enters with a positive sign and significantly at the 10 percent confidence level. On this evidence, differences in capital-labor ratios do indeed increase trade. However, once North-South is added (column 5), the variable becomes totally insignificant. Moreover, the significance of North-South stays just the same. Thus, even though differences in per capita output are relevant, whatever these differences may reflect is contained in North-South.

The next robustness tests introduce climatic data about average annual temperature, seasonal variation in annual temperature, and average annual rainfall. This data comes from the website worldclimate.com and it is recorded for the same geographical points serving to locate countries (the points of maximum population) and therefore to measure North-South. The information at this website makes it possible to preserve all but 200 of the observations in the estimates of equations (7) and (8). If North-South matters on account of climatic influences alone, this should emerge in the next series of tests (columns 6 through 9).

All three climatic series (in logs) are significant when entered separately, the difference in annual temperature variation exceptionally so, the difference in rainfall least but still nearly so at the 5 percent confidence level (columns 6, 7, and 8). However, all three series become unimportant when paired with North-South. Column 9 shows what happens when all three climatic variables are included together with North-South. They are all insignificant while North-South is totally unaffected. (Adding Difference in Per Capita Real GDP changes nothing.) I conclude that the hypothesis that North-South differences reflect opportunities for profitable trade holds up well. Differences in per capita output, temperature, rainfall, and seasonal variation in temperature all bear relevant information about comparative advantage. However, distances North-South capture all of this information and much more. In sum, the idea that differences North-South widen the range of goods in the world opportunity set and thereby enhance world trade receives ample confirmation.

Table 2 shows the results of dividing up the series by year. This next evidence carries the additional benefit of tracing the movement of the influence of North-South over time. As the estimates are annual, the output variable drops out and missing data for output ceases to be relevant. Thus, some 6,400 additional observations enter. (This is not true if unitary elasticity of output is imposed, as in this case the dependent variable becomes the ratio of trade to output.[3]) As seen in the top part of the table, the influence of North-South remains clear for each separate year. But the influence of the variable also falls over time. The coefficient of

[3] To be exact, the dependent variable then becomes the log of the ratio of bilateral trade to the product of the real GDPs. But the results stay the same.

North-South drops regularly except in 1980 to 1985. It goes from .26 to .11 In addition, the statistical significance of the coefficient remains high throughout, even when the coefficient is at its lowest or at the end-date, 1995. Accordingly, disregarding North-South as a separate variable could lead to a .15 increase in the negative impact of distance, tout court, over the period. If not exactly, this is close to what happens.

In the bottom part of the table, I repeat the estimates for distance at the top without North-South, but only show the estimate for distance to economize on space. There is a .22 rise in the negative impact of distance over the period, that is, twice as much as the rise from 1970 to 1995 at the top (or .11 more rather than .15). A closer look at the results leaves little doubt that the neglect of North-South plays a big role in the explanation. Based on the coefficient of –1.36 for distance and .26 for North-South for 1970 at the top, we might have expected a value of the coefficient of distance of –1.10 for this year at the bottom. The actual figure is –1.17, not quite as low as anticipated (in absolute terms) but well below the –1.36 figure at the top (by .19). Given the coefficient of –1.47 for distance and .11 for North-South at the top for the end-year 1995, we might have expected a coefficient of Distance of –1.36 for this year at the bottom. The actual figure is close: –1.39. These matches at start and finish clearly indicate that the disregard of the influence of North-South explains much of the rise of the influence of Distance from –1.17 to –1.39 (even if it is not the whole story).

As mentioned earlier, Disdier and Head (2004) find this rise in the influence of distance to be a basic result in their meta-analysis of 78 earlier papers. They estimate the rise as .24 from 1870 to 2000, all of it coming since 1960, which is quite in line with my figure of .22 for 1970 to 1995. The problem of explaining this rise in the effect of distance has already attracted a good deal of attention. The difficulty has always been to reconcile the tendency with the falling cost of transportation. Hummels (1999) notably points out that the cost of ocean transport follows no downward trend in the post-World War II period. For this reason, transportation costs as a whole possibly did not drop as much as we might imagine. But while clearly relevant, this observation will not explain why distance has even risen in influence since World War II. According to the present discussion, the rise in influence – at least half of it – has a simple explanation. It has nothing to do with transport costs but simply the shift in the composition of trade away from primary goods in agriculture and mining where differences in factor endowment are basic, toward sophisticated and highly differentiated products in manufacturing, where they are not. This shift in composition signifies a movement away from the sort of trade that rises with latitudinal distance and therefore can account for a good part of the rise in the negative coefficient of distance.

III. Remoteness and Internal Distance

Some aspects of distance are country-specific. To what extent do these aspects explain the country fixed effects and therefore play a role in the earlier estimates of bilateral trade? The fixed effects in equation (8) will serve in answering this question. I have also experimented with some of the variants of this equation in Table 1 and the conclusions are the same.

Two measures of remoteness will serve. One is the straight-line average of the distance of a country from all the rest, R_1. The other is the output-weighted average of this distance to all the rest, R_2. Specifically,

$$R_{1,i} = \frac{\sum_{i=1}^{c} d_{ij}}{C-1} \quad i \neq j \qquad R_{2,i} = \sum_{i=1}^{c} x_j d_{ij} \quad x_j = \frac{Y_j}{Y_W - Y_i} \quad i \neq j$$

where d_{ij} is the distance between i and j, C is the number of countries and x_j is the weight of country j's output in the output of the rest of the world. (Equivalent measures of R_2 appear in Wei (1996), Frankel (1997) and Wolf (1997).) R_2 is theoretically superior, since it counts every country's distance from the U.S., for example, more than its distance to Kiribati. The literature essentially uses R_2 rather than R_1.[4] Wei, who first introduced internal distance in gravity equations, measured the concept as a set fraction of the bilateral distance to some specific neighbor. Wolf preferred using the distance between two principal cities (but experimented with half the average distance to the bordering neighbors). Helliwell and Verdier (2001) developed a highly sophisticated measure of internal distance that takes into account the spatial distribution of the population within the country. Here I follow Nitsch (2000) in using land area to measure internal distance, or rather to construct such a measure. Suppose

[4] However, Helliwell champions a variant of R_2, concerning trade with *a particular partner*, which refers to the opposite pull coming from the attraction of trade with the other C−2 countries. Helliwell's measure depends on the others' distances on the one hand and their outputs – *working the opposite way* – on the other hand. See Helliwell (2002).

we regard all countries as perfect circles and thereby abstract from country shapes. Then if we divide the area by pi and take the square root, we have the radius or the distance from the center to the periphery. The radius is a fairly intuitive measure of internal distance. It has the distinct virtue of yielding universally available and internationally comparable numbers that plainly distinguish between countries on the basis of big and small.

The appendix shows how the 157 countries entering in the estimates rank based on R_1, R_2, and internal distance. As can be seen, the zone surrounding the central and eastern Mediterranean is the least remote part of the world based on R_1. Adopting the output-weighted measure instead, R_2, shifts the nadir of remoteness up North in Europe toward the Netherlands. Either way, the least remote countries are concentrated in Europe. The members of Oceania in the Pacific are always the most remote. There are asterisks besides 13 of the 157 countries in the appendix. These are all small countries in terms of population and output for which there are only a handful of observations in the study, mostly one or two. I performed the tests both for the full sample and for the sample without these 13 and the results are close. By preference, I shall report the results for the smaller sample of 144.

Besides remoteness and internal distance, the other variables in the estimates of the fixed effects are those mentioned in discussing equation (4). However, I add island and distance from the equator. Status as an island has occasionally served in earlier studies of the gravity model. Sachs and Warner (1997) and Rodriguez and Rodrik (2000) prominently use distance from the Tropics as an indicator of harshness of environment and poverty of endowment in studies of growth not trade. In light of the emphasis on latitude in this study, the distance from the tropics merits contemplation here. But, of course, being country-specific, this variable could not properly enter previously. Its measure is the absolute value of the latitude of the country, $|lat|$.

In the first estimate in Table 3, internal distance, output and population all come in highly significantly (in logs) with the expected signs. Of note, output has an elasticity of influence on trade of only .4, below the elasticity of influence of population of .5 (in absolute terms), and the theoretically required level of 1.[5] Evidently, therefore, the assumption of a unit-elasticity of output works with respect to movements in output over time but not on a cross-sectional basis. Landlocked is also nearly significant at the 10 percent confidence level. The correction for membership in the ex-Soviet Union is important. However, island, absolute latitude (in logs), and remoteness (in logs) are of no importance at all.

Remoteness refers to R_1 in column 1. The next column shows the outcome of substituting R_2, the output-weighted measure. There is no change at all. Column 3 removes the insignificant variables island and latitude, while keeping the theoretically preferable measure, R_2. The following column is the fruit of a separate inquiry into the possible non-linearity of the influence of remoteness. I made a number of tests of this possible non-linear influence: squaring remoteness, either before or after taking logs, and dividing it up in various ways between low, intermediate and high values. All the experiments fail miserably except one. The one success, appearing in column 4, results from assuming zero remoteness for the 20 or so least remote countries while keeping the rest of the series unchanged (the column shows the outcome with exactly 20 zeros). Upon reflection, this hypothesis is similar to supposing that remoteness has a negative effect everywhere except in Europe. The last column adopts this last hypothesis. More precisely, the column shows the outcome of assuming that all European countries except Iceland, Cyprus and Malta (24 countries in all) do not suffer at all from remoteness while the rest do. There is then a clear negative effect of remoteness that is distinctly statistically significant. The elasticity of influence of remoteness – where it applies – is .02. This last conclusion hinges on the measure R_2. Using R_1 shifts the 20 or so lowest values of remoteness toward the ancient Mediterranean world and the hypothesis ceases to work.

On the other hand, internal distance is always highly significant with an elasticity of influence of around .21. Of course, this elasticity depends on the measure of internal distance and would be smaller with a higher measure. However, any reasonable alternative could not be very different from the present one in any sample covering 144 countries.

[5] If instead of the fixed effects of equation (8), we use those in the estimate of this equation once unitary elasticity of output is imposed, the coefficients of the log of real output rise by about .06 to .46 and otherwise nothing mentionable changes. This holds for the remaining columns of Table 3 as well.

It is interesting to compare the impact of internal and external distance. Unfortunately, the comparison is difficult to make. As a preliminary, the estimates of internal and external distance relate to joint effects with the elasticity of substitution between goods. Obstfeld and Rogoff (2000) consider this last elasticity (σ of equation (6)) on average to be 6, Anderson and van Wincoop (2004) consider it closer to 8. On this basis, the relevant parameters pertaining to internal and external distance in equations (3) and (4) require dividing the previous estimates by a factor of 5 to 7. But the relative levels of the two parameters stay the same. Far more important then is the fact that the estimates for internal and external distance necessitate a different interpretation.

The coefficients of internal distance refer to an impact on foreign relative to domestic trade, while the estimates of external distance have nothing to do with aggregate foreign trade. The latter strictly concern the composition of foreign trade between different partners. For example, the –1.3 coefficient for distance between two countries says that they trade 1.3 percent more with one another (altogether, that is, given σ) than either one does with a third country that is 1 percent further away from itself.[6] It is therefore not clear from the estimate of around –.21 for internal distance (Table 3) and –1.38 for foreign distance (equation (8)) that internal distance is any less important than foreign distance. Consider the set of all foreign countries with which a country trades but does so less on account of foreign distance (roughly half of those with which it trades on average). In terms of elasticities, internal distance reduces bilateral trade with these countries by about 2/13 as much as external distance. But internal distance also reduces the country's trade with the rest and it reduces its aggregate foreign trade. On the other hand, external distance does not, or more accurately, it only does so

[6] This interpretation depends on the presence of country fixed effects. In their presence, distance refers strictly to relative distance: the distance between two countries relative to their distance to everybody else. To expand, suppose we were to divide the distance between a country pair (the level, not the log) by the square root of the product of R_1 of the two countries or the product of R_2 between them (the square root in order to keep the order of magnitude the same). The result would then be relative distance. After converting the ratio into logs and performing the earlier regressions in equations (7) and (8), the estimates would be *identical*. Only the fixed effects would be affected. I got a different result in Melitz (2004) only because I calculated remoteness based on all of the countries in the database rather than solely those that enter in the estimate and for which there are fixed effects in the estimates.

in connection with remoteness. Thus, as far as external distance affects aggregate foreign trade, which is strictly outside of Europe, the elasticity of influence of internal distance is about 10 times higher.

4. Conclusion

This paper takes a new, perhaps more general look at the role of distance in the gravity model. Most importantly, it questions the presumption that distance merely reflects frictions interfering with trade. Increasing distance North-South may mean wider differences in endowment and therefore more opportunity for profitable trade. The data strongly support this idea. The positive influence of North-South survives a battery of robustness tests. We can admit differences in per capita output; we can allow for the separate role of differences in temperature, rainfall, and seasonal variation; we can do all of these things together. Nothing ever even mildly disturbs the importance of the North-South variable or its coefficient at all. We can also distinguish the impact of North-South in the Northern and Southern hemispheres and in inter-hemispheric trade: all three parts are important and their coefficients are reasonably similar. Furthermore, the impact of distance North-South has clearly declined over recent decades. Disregarding North-South as a variable will then give the impression of a rising influence of distance on foreign trade. However, the *associated* rise in influence, so far as it exists, has nothing to do with transport costs.

In addition, the paper looks at the role of remoteness and internal distance. Remoteness emerges as only of modest significance. The variable has any role to play only once we cease to apply it at the low end, and even then, its impact, where present, is relatively small – at least as compared with that of internal distance, which is a major consideration. Larger countries do trade substantially less with foreigners than small ones, even after controlling for many other influences. In general, there are various indications in the paper that the role of distance and travel is particularly important at close range. The significance of a common border says that there is a tendency to favor foreign trade with the closest foreigner(s) irrespective of mileage. The role of internal distance also speaks to the significance of nearness.

If the size of a country matters, this must be true at least in the vicinity. In line with this assessment, the low significance of remoteness implies that global considerations about location are largely subordinate.

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Table 1: Distance North-South: Further Tests

	(1)	(2)	(3)	(4)	(5)
Log product of Real GDP	1.06 (28)	1.06 (28)	1.06 (28)	1.14 (29)	1.15 (29)
Log Distance	–1.38 (–46)	–1.31 (–46)	–1.38 (–46)	–1.23 (–43)	–1.38 (–43)
Log North-South			**.21 (7.4)**		**.21 (10)**
Log North-North	**.18 (8.35)**				
Log North-South (across hemi-spheres)	**.27 (3.01)**				
Log South-South	**.21 (6.58)**				
Log Difference in Latitudes		**.11 (6.28)**	**– .03 (–1.23)**		
Log Difference in Per Capita Real GDP				**.025 (1.73)**	**.004 (.32)**
Common Border (0, 1)	.53 (4.19)	.48 (3.83)	.53 (4.17)	.49 (3.76)	.57 (4.47)
Common Language (0-1)	.9 (12)	.91 (12)	.9 (12)	.92 (12)	.86 (11)
Currency Union (0, 1)	.91 (4.84)	.93 (4.99)	.91 (4.87)	1.02 (4.5)	1.07 (4.7)
Political Union (0,1)	.68 (1.86)	.65 (1.77)	.67 (1.82)	.57 (1)	.6 (1.07)
Free Trade Area (0,1)	.37 (3.02)	.65 (3.06)	.67 (2.97)	.57 (.76)	.6 (1.1)
Ex-Colonial Relationship (0,1)	1.56 (13)	1.58 (13)	1.56 (13)	1.63 (13)	1.58 (12)
Ex-Common Colonizer (0,1)	.64 (8)	.63 (7.82)	.64 (7.97)	.58 (6.99)	.64 (7.73)
R^2	.63	.63	.64	.64	.64
RMSE	2	2	1.99	1.99	1.99

Regressand is log of bilateral trade in real American dollars.
Number of Observations is 31,001 for the first three columns, 29,042 for the last two. The observations concern 157 countries in the first three columns, 143 in the last two.
All estimates include year-specific and country-specific fixed effects. These are not reported.
Student t in parentheses.

Table 1: Distance North-South: Further Tests (cont.)

	(6)	(7)	(8)	(9)
Log product of Real GDP	1.06 (28)	1.06 (28)	1.06 (28)	1.07 (28)
Log Distance	–1.27 (–46)	–1.26 (–45)	–1.29 (–46)	–1.39 (–45)
Log North-South				**.18** **(8.08)**
Log Difference in annual Temperature	**.045** **(2.76)**			**–.017** **(–.93)**
Log Difference in annual Rainfall		**.03** **(1.93)**		**.017** **(1.03)**
Log Difference in Seasonal Variation in annual Temperature			**.05** **(4.35)**	**.019** **(1.5)**
Common Border (0, 1)	.42 (3.3)	.41 (3.21)	.41 (3.23)	.51 (3.97)
Common Language (0-1)	.93 (12)	.94 (13)	.94 (13)	.9 (12)
Currency Union (0, 1)	.83 (4.48)	.83 (4.51)	.85 (4.54)	.84 (4.55)
Political Union (0,1)	.67 (1.78)	.64 (1.71)	.64 (1.69)	.69 (1.86)
Free Trade Area (0,1)	.35 (2.88)	.33 (2.63)	.34 (2.75)	.37 (3.04)
Ex-Colonial Relationship (0,1)	1.6 (13)	1.62 (13)	1.61 (13)	1.57 (13)
Ex-Common Colonizer (0,1)	.63 (7.8)	.6 (7.48)	.6 (7.53)	.65 (7.98)
R^2	.73	.73	.73	.73
RMSE	1.72	1.72	1.72	1.72

Regressand is log of bilateral trade in real American dollars.
Number of Observations is 30,911. The observations concern 156 countries.
All estimates include year-specific and country-specific fixed effects. These are not reported.
Student t in parentheses.

Table 2: Distance North-South: by year

	1970	1975	1980	1985	1990	1995
Log Distance	**–1.36 (–27)**	**–1.42 (–30)**	**–1.41 (–34)**	**–1.41 (–34)**	**–1.41 (–38)**	**–1.47 (–39)**
Log North-South	**.26 (8.08)**	**.21 (6.76)**	**.18 (6.23)**	**.14 (4.94)**	**.14 (5.65)**	**.11 (4.25)**
Common Border (0, 1)	.5 (2.84)	.37 (2.29)	.66 (4.08)	.49 (2.98)	.56 (3.67)	.57 (3.16)
Common Language (0-1)	1.1 (9.39)	.96 (8.43)	.8 (7.97)	.78 (7.72)	.82 (8.94)	1.02 (12)
Currency Union (0, 1)	.97 (2.95)	.93 (2.95)	.99 (4.26)	1.15 (4.31)	1.27 (4.11)	.83 (2.43)
Political Union (0,1)	.7 (1.48)	1.33 (3.22)	1.48 (3.67)	1.86 (4.22)	.81 (1.09)	1.2 (3.1)
Free Trade Area (0,1)	.05 (.18)	.41 (1.81)	.3 (1.68)	.46 (2.8)	.37 (2.76)	–.06 (–.42)
Ex-Colonial Relationship (0,1)	1.69 (9.04)	1.6 (9.3)	1.63 (13)	1.51 (12)	1.38 (11)	1.11 (8.22)
Ex-Common Colonizer (0,1)	.72 (5.91)	.71 (5.35)	.66 (5.43)	.6 (4.99)	.56 (5.49)	.35 (3.12)
R^2	.71	.7	.73	.735	.78	.81
RMSE	1.8	1.9	1.75	1.69	1.56	1.45
Number of observations	5279	5877	6441	6257	6603	5994
Number of countries	138	141	156	156	156	154

Log Distance	**–1.17 (–27)**	**–1.28 (–31)**	**–1.28 (–36)**	**–1.31 (–36)**	**–1.31 (–40)**	**–1.39 (–41)**
R^2	.71	.7	.72	.73	.78	.81
RMSE	1.82	1.91	1.76	1.7	1.57	1.46

Regressand is log of bilateral trade in real American dollars.
All estimates include year-specific and country-specific fixed effects. These are not reported.
Student t in parentheses.

Table 3: Internal Distance and Remoteness

	(1)	(2)	(3)	(4)	(5)
Log Remoteness 1	**.18 (.47)**				
Log Remoteness 2		**.07 (.17)**	**.18 (.47)**		
Log Remoteness 2 except for lowest 20				**–.022 (–2.85)**	
Log Remoteness 2 outside of Europe					**–.019 (–2.56)**
Log Internal Distance	**–.24 (–2.96)**	**–.23 (–2.87)**	**–.24 (–3.28)**	**–.21 (–2.95)**	**–.21 (–2.95)**
Landlocked (0, 1)	–.27 (–1.54)	–.27 (–1.55)	–.29 (–1.64)	–.42 (–2.41)	–.39 (–2.27)
Island (0, 1)	–.01 (–.05)	.01 (.08)			
Log Distance from the Equator	–.06 (–.82)	–.06 (–.76)			
Log Population	–.5 (–6.02)	–.5 (–6.01)	–.48 (–6.15)	–.41 (–5.43)	–.42 (–5.41)
Log Real GDP	.4 (5.81)	.4 (5.65)	.38 (5.96)	.28 (4.36)	.28 (4.3)
Ex-USSR (0, 1)	–.66 (–2.39)	–.67 (–2.38)	–.69 (–2.47)	–1.09 (–3.79)	–1.1 (–3.7)
$\bar{R}^2$	.51	.51	.52	.54	.53
RMSE	.67	.67	.66	.64	.64

Regressand is the estimate of the fixed of equation (8).
Number of observations is 144.
Student t in parentheses.
Remoteness 1 = the straight-line average of distances over the remaining 143 countries.
Remoteness 2 = the sum of the output-weighted distances to the remaining 143 countries.
Remoteness 2 except for lowest 20 = Remoteness 2 with zeros for the lowest 20 values.
Remoteness 2 outside of Europe = Remoteness 2 with zeros for European countries (24, excluding Iceland, Malta and Cyprus)

Appendix: Remoteness and Internal Distance

in ascending order

	Remoteness 1 Straight-line average	Remoteness 2 Weighted-average	Internal Distance in miles
1.	Malta	Netherlands	Bermuda* 4.1
2.	Tunisia	Germany, West	Montserrat* 5.7
3.	Italy	Belgium	British Virgin Islands* 7
4.	Greece	Germany, East	Cook Islands* 8.7
5.	Algeria	Denmark	St.Pierre & Miquelon* 8.8
6.	Bulgaria	United Kingdom	St. Kitts and Nevis 9.1
7.	Egypt	Czechoslovakia	Maldives 9.8
8.	Serbia/Montenegro	France	Malta 10
9.	Switzerland	Switzerland	Grenada 10.5
10.	Turkey	Norway	St. Vincent & Gren. 11.1
11.	Hungary	Poland	Barbados 11.7
12.	Austria	Sweden	Antigua & Barbuda* 11.9
13.	Spain	Austria	Seychelles 12.0
14.	Romania	Ireland	St. Lucia 13.9
15.	Cyprus	Finland	Bahrain 14.5
16.	Israel	Hungary	Singapore 14.7
17.	Morocco	U.S.S.R.	Dominica* 15.5
18.	Lebanon	Serbia/Montenegro	Kiribati* 16.1
19.	Czechoslovakia	Italy	Solomon Islands 17
20.	Germany, West	Romania	Hong Kong China 18.2
21.	Jordan	Bulgaria	Martinique* 18.4
22.	Syria	Iceland	Guadeloupe* 23.3
23.	France	Spain	Mauritius 25.4
24.	Portugal	Turkey	Comoros 26.3
25.	Niger	Tunisia	Reunion 28.2
26.	Chad	Algeria	Trinidad and Tobago 40.4
27.	Belgium	Greece	French So. Ant. Territ. 49.9
28.	Germany, East	Portugal	Cyprus 54.2
29.	Netherlands	Malta	Gambia The 56.4
30.	Burkina Faso	Greenland*	Bahamas The 56.6
31.	Poland	St. Pierre & Miquelon*	Lebanon 57.1
32.	United Kingdom	Morocco	Jamaica 58.7
33.	Sudan	Cyprus	Qatar 60.3
34.	Mali	Lebanon	Kuwait 75.3
35.	Denmark	United States	Fiji 76.3
36.	Nigeria	Syria	New Caledonia* 76.9
37.	Benin	Canada	Israel 80.4
38.	Iraq	Israel	El Salvador 81.2
39.	Togo	Jordan	Belize 85.2
40.	Mauritania	Egypt	Djibouti 85.5
41.	Congo Demo Rep	Iraq	Rwanda 89.1
42.	Congo Rep.	Iran	Burundi 90.4
43.	Ireland	Kuwait	Haiti 93.7
44.	Cameroon	Bermuda*	Guinea-Bissau 94.4
45.	Central African Rep	Bahrain	Belgium 98.2
46.	Ghana	Saudi Arabia	Taiwan 101
47.	Cote d'Ivoire	Qatar	Netherlands 104
48.	Senegal	United Arab Emirates	Switzerland 113
49.	Saudi Arabia	Mongolia	Denmark 116
50.	Kuwait	Mauritania	Bhutan 122
51.	Gambia	Oman	Dominican Republic 124
52.	Guinea-Bissau	Pakistan	Costa Rica 127
53.	Guinea	Sudan	Togo 132
54.	Sweden	Niger	Sri Lanka 144
55.	Sierra Leone	Senegal	Ireland 148
56.	Norway	Bahamas The	Sierra Leone 151
57.	Gabon	Nepal	Panama 156

58. Liberia	Burkina Faso	Austria 162
59. Ethiopia	Mali	United Arab Emirates 162
60. Bahrain	Gambia	French Guiana* 168
61. Iran	Chad	Portugal 171
62. Finland	Bhutan	Jordan 171
63. Qatar	Guinea-Bissau	Hungary 171
64. U.S.S.R.	British Virgin Islands*	Malawi 173
65. Djibouti	India	Liberia 175
66. Uganda	St. Kitts and Nevis	Korea Rep. 177
67. United Arab Emirates	Antigua and Barbuda*	Germany, East 178
68. Rwanda	Montserrat*	Iceland 179
69. Burundi	Dominican Rep	Serbia/Montenegro 180
70. Kenya	Guadeloupe*	Guatemala 186
71. Oman	Korea Rep.	Bulgaria 188
72. Somalia	Guinea	Benin 188
73. Angola	Haiti	Honduras 189
74. Iceland	Bangladesh	Nicaragua 196
75. Tanzania	Djibouti	Czechoslovakia 200
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