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Declining Distance Effects in International Trade: Some Country-Level Evidence

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Abstract

Technical progress can be expected to reduce transport costs over time, yet most studies of bilateral trade based on the gravity model find distance effects to be increasing rather than decreasing. We investigate countries' openness to international trade (the ratio of exports plus imports to GDP). We find that trade decreases with geographical remoteness, land area, and lack of access to the sea, all of which are likely to be correlated with transport costs. In contrast to results obtained with log-linear models of bilateral trade, distance effects (remoteness and land area) have declined over time. Trade decreases with population density, and increases with improvements in the terms of trade, investment and a more liberal trade policy. Unlike in the case of bilateral trade, our results are robust to the transformation of the dependent variable.

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1) Introduction

A voluminous literature has examined the determinants of bilateral trade flows, mostly based on the "gravity" model, according to which trade increases with economic mass and decreases with distance. A puzzling feature of this research is that, despite the apparent technical progress in the transport industry, distance appears to be getting *more* rather than *less* important as a deterrent to trade (e.g. Berthelon and Freund, 2008; Brun *et al*., 2005; Leamer and Levinsohn, 1995). In a meta-regression analysis of 103 studies, Disdier and Head (2008) find that the estimated distance effect has increased significantly over time since 1950, although it had a tendency to decline slightly before that.

Because the typical log-linear specification has difficulties with zero or near-zero observations (Coe *et al*., 2007), it is possible that this result is driven by large proportional changes in the smallest bilateral trade flows that represent a negligible proportion of world trade. For example Coe *et al*. (2007) find that, when the dependent variable is not in logarithmic form (so that the biggest shifts over time tend to be in country-pairs with the biggest flows), distance effects are indeed declining. It appears that the puzzle merits further investigation.

The contribution of this paper is to approach the issue in a different way, by using country-level data on the ratio of international trade to GDP. Having found that variables that can be regarded as proxies for transport costs in international trade significantly affect this ratio, we investigate whether their influence has declined over time. In effect, we are asking whether countries with high transport costs in international trade have become more open relative to those with low transport costs, *ceteris paribus*, as would be expected if transport costs were declining. The answer that the data give us to this question is "Yes", which supports the contention of Coe *et al*. (2007) that transport-cost effects in international trade are truly declining. An important feature of our results is that they are similar whatever transformation of the dependent variable is used.

We investigate openness to international trade at the country level, which is the sum of bilateral trade flows divided by GDP, in a panel data set from 1980 to 2005. This enables us to focus more closely on the country-specific determinants of trade, such as geography, trade policy and macroeconomic conditions, which in bilateral trade models tend increasingly to be absorbed in country fixed effects (and therefore to remain uninvestigated), following the arguments of Anderson and Wincoop (2003), although Baier and Bergstrand (2009) have recently presented the case for explicitly modelling these "multilateral resistance" factors. It also has the advantage that we have no zero or near-zero observations, which pose problems for the log-linear specification most commonly used in bilateral trade models (Coe *et al*., 2007). A related point is that the dependent variable is far less heteroscedastic than in bilateral trade flows, the highest value being less than ten times the lowest. Moreover we can easily extend our model to estimate how these country-specific determinants vary over time. Unlike most bilateral trade studies (Berthelon and Freund, 2008; Brun *et al*., 2005; Leamer and Levinsohn, 1995), we find that distance and country size effects, both of which seem likely to be indicators of transport costs, have significantly declined.

In its cross-country dimension our work is quite closely related to that of Guttmann and Richards (2006), but they do not investigate the time dimension of trade openness or time variation in cross-section effects.

2) Model

As shown in Feenstra (2004), a model of trade theory with imperfect competition can be used to derive a gravity model of international trade, in which bilateral exports are a function of output in the two countries and of the relative price of the exporting country's goods in the importing country:

$$X_{ij} = Y_i Y_j \left[\frac{p_i T_{ij}}{P_j} \right]^{1-\sigma} \tag{1}$$

where X_{ij} represents exports from country *i* to country *j*, Y_i and Y_j are the two countries' outputs, p_i is the price of goods produced in country *i* (before transport costs), P_j is the aggregate price index in country *j*, $T_{ij} (> 1)$ represents iceberg transport costs from country *i* to country *j*, and $\sigma (> 1)$ is the elasticity of substitution between products. Aggregating over all countries importing from country *i*, we obtain:

$$X_i = \sum_j X_{ij} = Y_i \sum_j Y_j \left[\frac{p_i T_{ij}}{P_j} \right]^{1-\sigma} \tag{2}$$

By symmetry, imports of country *i* (M_i) sum to:

$$M_i = \sum_j X_{ji} = Y_i \sum_j Y_j \left[\frac{p_j T_{ji}}{P_i} \right]^{1-\sigma} \tag{3}$$

The price index in country j is given by the CES formula:

$$P_j = \left[\sum_{k=1}^{N} (p_k t_{kj})^{1-\sigma} \right]^{1/(1-\sigma)} \tag{4}$$

Summing equations (2) and (3) and dividing by country i's output yields:

$$\left(\frac{X+M}{Y} \right)_i = \sum_j Y_j \left[\left(\frac{p_i T_{ij}}{P_j} \right)^{1-\sigma} + \left(\frac{p_j T_{ji}}{P_i} \right)^{1-\sigma} \right] \tag{5}$$

Under the assumption of symmetrical bilateral trade costs ($T_{ij} = T_{ji}$), equation (5) becomes:

$$\left(\frac{X+M}{Y} \right)_i = \sum_j Y_j T_{ij}^{1-\sigma} \left[\left(\frac{p_i}{P_j} \right)^{1-\sigma} + \left(\frac{p_j}{P_i} \right)^{1-\sigma} \right] \tag{6}$$

which expresses a country's trade to GDP ratio as a function of average transport costs to other countries and relative prices, weighted by their GDP. Baier and Bergstrand (2009) show that, in the case of bilateral trade, the relative price terms give rise to multilateral resistance effects that can be represented as GDP-weighted averages of the bilateral transport costs for each of the pair of countries. In the present case, bilateral trade flows are being summed over all partner countries, which gives rise to a GDP-weighted average of the multilateral resistance term for all partner countries (in the context of bilateral trade, the multilateral resistance terms can be modelled as country fixed effects, but with data aggregated to the country level, as here, this approach is inappropriate).

After confirming that transport costs matter for the trade-GDP ratio in a cross-country sample, we then use panel data to explore how their effect has changed over time.

Our cross-section regressions are based on log-linearizing (6), and are of the form:

$$\ln\left(\frac{X+M}{Y}\right)_i = \alpha + \underline{\beta}.\underline{TC}_i + \underline{\gamma}.\underline{\left(\sum_{j\neq i} Y_j TC_j\right)} + \underline{\delta}.\underline{CONTROLS}_i + u_i \qquad (7)$$

where i is an index of countries; $\underline{TC}$ and $\underline{CONTROLS}$ are vectors of transport cost measures and control variables respectively, as described in the next section; $\alpha, \underline{\beta}$, $\underline{\gamma}$ and $\underline{\delta}$ are parameters to be estimated; and u is an error term. Equation (7) espresses the natural logarithm of the trade/GDP ratio of country i as a function of transport cost measures for country i, GDP-weighted average transport cost measures for all other countries, and a set of control variables. At the second stage we use panel data to investigate whether $\underline{\beta}$ and $\underline{\gamma}$ have varied over time:

$$\ln\left(\frac{X+M}{Y}\right)_{it} = a_i + \underline{b}.(\underline{TC} * TIME) + \underline{c}.[(\sum_{j\neq i} Y_j \underline{TC_j}) * TIME] + \underline{d}.\underline{CONTROLS}_{it} + v_{it} \qquad (8)$$

In this regression transport costs are omitted (except when interacted with time) because of collinearity with the country fixed effects (a_i). We then check the results of equation (8) using the Fixed Effects Vector Decomposition method of Plümper and Troeger (2007), which is a variant of pooled ordinary least squares that allows for unidentified country fixed effects, as explained below.

3) Data

In this section we describe the data. The measure of openness (the ratio of exports plus imports to GDP) is obtained from the World Bank's World Development Indicators (WDI) database. We transform this ratio by taking the natural logarithm. This log-linear transformation is the form most frequently used in empirical studies of bilateral trade (Disdier and Head, 2008). At a later stage we examine the robustness of our results to different transformations of the data (a simple ratio, and the natural logarithm of one plus the trade ratio), because this has been an issue of some importance in empirical studies of bilateral trade.

We use several variables to measure transport costs. One is a measure of the great-circle distance between the most important cities in each pair of countries, weighted (for the purpose of calculating this measure for country *i*) by the GDP of each partner country. We then take the natural logarithm of this weighted average.[1] We refer to this variable, which is the country-level equivalent of distance as used in models of bilateral trade, as "remoteness".

A second measure of transport costs is the log surface area of each country in square kilometres, as given in WDI. Land area may be considered a measure of transport costs in international trade, because in larger countries the average point is further from the border. This helps to correct for the fact that the economic activity of a country is not concentrated all

[1] The source of the distance data is the website of the *"Centre D'Etudes Prospectives et D'Information Internationales"* (CEPII) at http://www.cepii.fr/anglaisgraph/news/accueilengl.htm.

in one point, as the remoteness measure effectively assumes.[2] For example, consider two neighbouring countries A and B, that are similar in all respects except with A having a much larger land area. The border will be closer to the economic centre of B than to the economic centre of A, which implies that B will tend to have lower transport costs in international trade.

The third measure of transport costs is a dummy for lack of access to the sea (source: CIA Factbook website), which has also often been used in bilateral trade models.

Also included are multilateral resistance factors (GDP-weighted averages of trading partners' measures) for each of these variables, that are denoted "ROW" (Rest of the World) in the regression results. Whereas each of the transport cost measures is expected to have a negative coefficient, the expected sign of the ROW factors is positive.

To capture non-natural trade costs such as tariff barriers, we use the measure of "Freedom for Trade" created by James Gwartney and Robert Lawson with William Easterly for the Economic Freedom of the World: 2007 Annual Report published by the Fraser Institute. In their own words this variable *"measures the extent to which nations allow their citizens economic freedom. From the beginning, the freedom of people to trade internationally has been a featured area within the index."* The index runs from 1 to 10, where one represents a closed economy with several barriers to reach trade agreements with different nations and ten represents a very open economy that engages easily in trade with other nations. Since this

[2] For example, in a circle of radius *r*, the average distance of each point from the circumference is $\int_0^r 2\pi x(r-x)dx$ divided by πr^2, which comes out as *r*/3, so it increases in proportion to the radius.

index was calculated only every five years until 2000, starting in 1975, some interpolation is necessary for the time series dimension of our study.[3] In the cross-section part of our analysis we take the average of the years 1985, 1990, 1995 and 2000 to construct our 20-year average measure. Otherwise the index is as given in the original source.

For the cross-section aspect of our work, we also include the following control variables: the share of gross investment in GDP, the log of population density, and the log of per capita real GDP in 2000 US dollars (or alternative a dummy for high-income countries). All these variables are from WDI. The investment ratio is included because exports of tradable capital goods are much more geographically concentrated than those of tradable consumption goods, so countries that invest more are likely to import (and therefore also to export) a larger share of their output. Population density (entered in logarithms) is expected to affect trade negatively, because with higher population the country can produce more varieties of each good to satisfy local consumers' love of variety. We use population density rather than population to avoid collinearity with land area. An alternative way of interpreting this variable is that it captures the population effect after controlling for transport cost effects captured by land area. Finally, per capita GDP (in logarithms) is a standard control variable. We also present some results with a dummy for high-income countries (as defined in WDI) instead of per capita GDP.

In the panel data, we also include a terms-of-trade index (in logarithms, from WDI), fluctuations in which are liable to affect the ratio of trade to GDP. For example, countries

[3] We set the values for 1981, 1982, 1983 and 1984 equal to the reported value for 1985, and similarly for subsequent five-year periods.

that experience an export price boom are likely also to import more, and to find trade increasing relative to GDP.[4] Other variables that are not fixed across time, such as investment and Freedom for Trade, also feature in our fixed-effects panel regressions, but those that are fixed across time (such as land area) are collinear with country fixed effects. Nevertheless these time-invariant variables can be included in interaction form, and this is an important part of our analysis.

4) Results

We begin with our cross-section results (Section 4.1). We follow this with a standard country fixed-effects regression, to investigate time trends and the evolution of the transport cost coefficients over time (Section 4.2). In Section 4.3 we repeat this analysis whilst modelling country fixed effects more explicitly. Some robustness tests are presented in Section 4.4.

4.1 Cross-country Results

For our cross-section we use twenty-year averages for the period 1981-2000. The variables are as described in Section Three. The regressions are quite similar to those estimated for six successive five-year periods from 1971-75 to 1996-2000 by Guttmann and Richards (2006), except that these authors do not include the ratio of investment to GDP or the multilateral resistance factors in the regression. The results are shown in Table 1.

[4] Obviously the terms of trade are meaningless in a cross-section regression, because the index is arbitrarily set to 100 for each country in the chosen base year.

Table 1. Determinants of trade openness in a cross-section of countries

Dependent variable: ln[100(X+M)/Y]		
Independent variables	(1)	(2)
ln (remoteness)	-0.246** (-1.99)	-0.335*** (-2.80)
ln (area)	-0.219*** (-10.6)	-0.208*** (-11.0)
Landlockedness dummy	-0.220** (-2.05)	-0.150* (-1.79)
ROW ln (remoteness)	-2.50 (-0.46)	-3.25 (-0.61)
ROW ln (area)	0.088 (0.12)	0.219 (0.31)
ROW Landlockedness dummy	-39.1 (-1.09)	-33.4 (-0.98)
Freedom for Trade index	0.108*** (3.44)	0.0863*** (3.21)
ln (population density)	-0.188*** (-6.24)	-0.185*** (-6.19)
Investment/GDP	0.0231*** (3.37)	0.0174*** (2.77)
ln real GDP per capita	-0.123*** (-2.80)	
High income dummy		-0.368*** (-3.52)
Constant	30.55 (0.81)	34.91 (0.93)
Sample size	106	107
R-squared	0.658	0.669
Standard error	0.315	0.307

Notes. Variables are 1981-2000 averages. Figures in parentheses are *t*-statistics. *,**,*** denote significant at the 0.10, 0.05 and 0.01 levels respectively. “ROW” variables are multilateral resistance factors for trading partners.

The three transport cost variables (remoteness, area and a dummy for lack of access to the sea) all have the expected negative coefficient in Table 1. Area is much the most significant, with a *t*-statistic of over ten and an elasticity of about –0.2. Both remoteness and landlockedness are significant at the 5% level when real per capita GDP is included. With a high income dummy instead of real per capita GDP, remoteness is significant at the 1% level, but landlockedness is significant only at the 10% level. The elasticity of the trade ratio with respect to remoteness is similar to that for land area, at about –0.2. The multilateral resistance (ROW) variables are never statistically significant and not always of the expected positive sign.

The Freedom for Trade Index has a positive coefficient as expected, and it is significant at 1%, indicating that countries with fewer trade barriers have higher trade ratios, with each point on the index estimated to increase the trade ratio by 10%. Population density is highly significant and negative, with a *t*-statistic of about six and an estimated elasticity close to –0.2. This might be interpreted as a trade diversion effect of more trading opportunities within the country, possibly in connection with consumers' love of variety, as mentioned earlier. With more economic activity at home within a given area, internal trade displaces international trade. It is also true, since area and population density have similar coefficients, and since also in logarithms they sum to population, that one could argue that only population matters and not land area. The economic meaning of a pure population effect is unclear, however. We prefer to disaggregate it into an area and a population density effect, since the former is more clearly identified with transport costs in international trade than the latter, which is more of a reflection of domestic trading opportunities. Investment has a positive coefficient with a *t*-statistic of about three.

Per capita income effects are significantly negative, as also found by Guttmann and Richards (2006). The signs of our coefficients are similar to the ones that they report in their Table 1 for cross-sections over six five-year periods from 1971-75 to 1996-2000, with a sample size of 101 to 103 for the first four periods, 116 in 1991-95 and 120 in 1996-2000, even though they do not include investment in their regression. The goodness of fit of their regressions decreases markedly in the last two periods, when the sample size is larger.

4.2 Panel Results

Table 2 shows the results of estimating a fixed-effects model on annual data from 1980 to 2005 (random effects are always rejected in favour of fixed effects according to a Hausman test). We have an unbalanced panel of more than 2200 observations from 121 different countries. The baseline model shown in the first column of Table 2 includes the terms of trade, the investment ratio, Freedom for Trade, real per capita GDP and a time trend. With normal standard errors, all of these variables are significant at the 5% level, with positive coefficients, as shown in Appendix Table A1. With heretoscedasticity-robust standard errors, which in a fixed effect regressions are also clustered by country (as shown in Table 2), investment and the time trend are still highly significant, but the terms of trade, Freedom for Trade and per capita GDP are only marginally significant.

The positive coefficient on the Freedom for Trade Index indicates that trade liberalization within a country increases its trade ratio. So also does higher investment, although this may be capturing a pro-cyclical aspect of trade as well as the effect of longer-term shifts in countries' investment ratios. Real per capita GDP has a positive coefficient, probably because expenditure on traded goods is more cyclical than expenditure on non-traded goods.

The positive time trend in column (1) of Table 2 suggests that the openness ratio in the average country is increasing at about 1 % p.a., *ceteris paribus*.

The second column of Table 2 shows the results of tests for time trends in remoteness and in its multilateral resistance factor respectively. These time trends have the expected signs (under the assumption that transport costs are falling), but are not significant. Column (3) repeats this exercise for land area. This time the coefficient of the time trend for own-country land area is positive at the 1% level, as expected, but the time trend in ROW land area is also positive, although not significant. In column (4) of Table 2 we include time trends in remoteness, land area and the dummy for landlockedness, together with their multilateral resistance factors. The time trends in the three own-country variables are all positive, indicating that the negative effect of these factors on trade has fallen over time, although only the time trend for land area is individually significant. The multilateral resistance factors also have positive time trends, surprisingly. The F-test shows that the time trends in the own-country variables are collectively significant at the 1% level.

Table 2. Fixed Effect Regressions for Openness, 1980-2005

Dependent variable: ln[100(X+M)/Y]				
Independent variables	(1)	(2)	(3)	(4)
Freedom for Trade Index	0.0174* (1.67)	0.0181* (1.73)	0.0181 (1.62)	0.0188* (1.69)
Investment/GDP	0.0136*** (6.29)	0.0130*** (5.86)	0.0129*** (6.04)	0.0124*** (5.82)
ln real per capita GDP	0.119 (1.48)	0.152* (1.68)	0.110 (1.31)	0.120 (1.24)
ln terms of trade	0.0778* (1.80)	0.088** (2.04)	0.0635 (1.43)	0.0730 (1.57)
Time trend	0.00961*** (5.00)	0.00841*** (4.08)	0.00650*** (3.17)	0.00489** (2.21)
ln(remoteness)* time †		0.00665 (1.24)		0.00458 (0.86)
ln(area)*time †			0.00262*** (3.64)	0.00253*** (3.51)
Landlockedness* time †				0.000702 (0.12)
ROW ln (remoteness)*time		-0.0117 (-1.01)		0.00615 (0.53)
ROW ln(area)*time			0.0059 (1.18)	0.0136** (2.14)
ROW landlocked-ness*time				0.424** (2.35)
Joint F-test of coefficients marked †				F(3, 118) = 4.56***
Sample size	2231	2214	2214	2214
No. of countries	121	119	119	119
F-test of country fixed effects	129.6***	131.8***	100.2***	100.4***
Standard error	0.1794	0.1789	0.1762	0.1758

Notes. Time=1 in 1980, =2 in 1981 etc. Figures in parentheses are heteroscedasticity-robust *t*-statistics. *,**,*** denote significant at the 0.10, 0.05 and 0.01 levels respectively.

Apart from using different assumptions about the variance-covariance matrix (which affects the standard errors but not the point estimates of the coefficients), Table A1 also omits the ROW variables from the regression. This has little effect on the estimated time trends in the own-country transport cost variables, which tend to be significantly positive even if the ROW variables are omitted.

These results suggest that the deterrent effect of transport costs on international trade is truly declining, in contrast to the results found for bilateral trade with a similar log-linear specification (Disdier and Head, 2008), but consistent with those of Coe *et al*. (2007) with a non-log-linear specification. We show later that in this respect our results are robust to the specification of the dependent variable.

4.3 Fixed-Effects Vector Decomposition

Estimation with country fixed effects precludes the use of time-invariant explanatory variables, such as remoteness, that are collinear with the fixed effects, whilst pooled ordinary least squares (OLS) estimation does not allow for unobserved country fixed effects, which are potentially important. In this section we use the Fixed-Effects Vector Decomposition (FEVD) method of Plümper and Troeger (2007), which provides a way of introducing unobserved country fixed effects into a pooled OLS regression, and therefore of including variables that capture the cross-country variation in the dependent variable. The method consists of three stages. The first stage involves the estimation of a fixed-effects model like those shown in Table 2, but solely in order to estimate the country fixed effects. At the second stage the vector of country fixed effects from the first stage is regressed on country-averaged variables that might explain the cross-country variation in the dependent variable. The only purpose of the second stage is to generate a set of residuals that are purged of the cross-country differences that can be explained by the regressors; these residuals may be described as "unidentified country fixed effects". Finally, the third stage is a pooled OLS regression on all the regressors used in the first and second stages, plus the residuals from the second stage, which will capture unidentified country fixed effects. Unlike in Table 2, variables such as transport costs can be included in this regression in non-interaction form. In the case of variables which have both cross-country and time variation, such as investment, the estimated coefficient captures both components, as is normal with pooled OLS. The novelty is that the method permits the impact of time-invariant variables to be estimated, whilst also allowing for unobserved country fixed effects.

Table 3. FEVD Regressions for Openness, 1980-2005

Dependent variable: ln[100(X+M)/Y]			
Independent variables	(1)	(2)	(3)
ln (remoteness)	-0.335*** (-21.8)	-0.400*** (-13.1)	-0.403*** (-13.2)
ln (area)	-0.229*** (-90.2)	-0.264*** (-59.5)	-0.264*** (-58.0)
Landlockedness dummy	-0.197*** (-16.6)	-0.211*** (-9.32)	-0.212*** (-9.24)
ROW ln (remoteness)	0.511*** (5.01)	0.492*** (4.90)	1.14*** (4.27)
ROW ln (area)	0.0916** (2.24)	0.0675* (1.68)	-0.0427 (-0.43)
ROW Landlocked-ness dummy	-6.97*** (-3.20)	-8.55*** (-4.00)	-12.59** (-1.98)
Freedom for trade	0.0612*** (21.9)	0.0605*** (22.0)	0.0606*** (21.9)
ln (population density)	-0.202*** (-55.6)	-0.202*** (-56.6)	-0.202*** (-56.5)
Investment/GDP	0.0201*** (34.0)	0.0202*** (34.9)	0.0201*** (34.8)
ln real per capita GDP	-0.0637*** (-15.9)	-0.0637*** (-16.2)	-0.0634*** (-16.1)
ln terms of trade	0.0844*** (7.32)	0.0799*** (6.90)	0.0811*** (7.00)
Time trend	0.0097*** (13.5)	0.0082*** (10.97)	0.0074*** (8.97)
ln(remoteness)*time		0.0041** (2.37)	0.0044** (2.51)
ln(area)*time		0.0025*** (9.39)	0.0025*** (9.15)
Landlockedness dummy*time		0.0010 (0.76)	0.0010 (0.76)
ROW ln(remoteness)*time			-0.0430** (-2.54)
ROW ln(area)*time			0.0082 (1.31)
ROW Landlocked-ness dummy*time			0.183 (0.53)
Unidentified fixed effects	1.00*** (79.8)	1.00*** (81.4)	1.00*** (81.2)
Sample size	2214	2214	2214
R-squared	0.900	0.904	0.904
Standard error	0.1733	0.1700	0.1696

Notes. Time=1 in 1980, =2 in 1981 etc. Figures in parentheses are *t*-statistics. *,**,*** denote significant at the 0.10, 0.05 and 0.01 levels respectively. The FEVD method is a three-stage procedure as described in Plümper and Troeger (2007). The results shown are from the third (pooled OLS) stage. “Unidentified fixed effects” are the residuals from a regression of estimated fixed country effects on the country-averaged variables in the model.

In the basic version of this approach we use the variables shown in the first column of Table 2 (terms of trade, investment, real GDP, Freedom for Trade and a time trend) at the first stage; and remoteness, surface area, a dummy for landlockedness (including their multilateral resistance factors), population density, plus investment, real GDP and Freedom for Trade at the second stage. At the third stage (the only stage for which we report results) we use all these variables plus the residuals from the second stage. For regressors that are used at both the first and second stages, the results reflect both their cross-country and time variation, as in pooled OLS.[5]

The first column of Table 3 shows the results from the FEVD method without any variables being interacted with time. Variables that are largely time-invariant (which appeared in Table 1 but not Table 2) tend to have similar coefficients but larger *t*-statistics than in Table 1, because of the greatly increased sample size. These variables are remoteness, area, landlockedness (plus their ROW equivalents) and population density. The main differences are that the remoteness coefficient is rather more negative than in Table 1 (-0.34 as opposed to -0.25), and the ROW remoteness and area variables now have significant positive coefficients, as expected. The ROW landlockedness coefficient is however still negative.

Likewise the variables that did not appear in Table 1 (the terms of trade and the time trend) have coefficients similar to those in Table 2. The coefficients of variables that appeared in both Tables 1 and 2 (Freedom for Trade, investment and per capita GDP) now reflect both their time and their cross-country variation. In the case of investment and Freedom for Trade, the result is that they have larger positive coefficients than in Table 2, since they had

[5] See Plümper and Troeger (2007) for further details.

positive coefficients in Table 1. For per capita GDP, the estimated coefficient in Table 3 is significantly negative, which indicates that the negative cross-country effect in Table 1 dominates the positive cyclical effect in Table 2. Unidentified country fixed effects are also highly significant, which reflects the fact that the variables in the model do not fully explain the cross-country variation in the data.[6]

The second and third columns of Table 3 investigate how the remoteness, area and landlockedness effects have varied over time. The difference between columns (2) and (3) is that in column (3) time trends are also included for the ROW variables. In column (2) the time trends in remoteness and land area have significant positive coefficients, indicating that the negative effects on trade of these factors have been decreasing significantly over time. The coefficient of remoteness in column (2) of -0.400 is its estimated effect in 1979, when time is zero, and the coefficient of remoteness times time of +0.0041 indicates that this effect is declining by about 1% (=0.0041/0.400) of its 1979 value each year. Likewise, the estimated effect of area in 1979 of -0.264 is estimated to have a trend of +0.0025 per year, or again about 1% of its 1979 level. For landlockedness, the estimated decline in the negative effect is smaller, at only about 0.5% of its 1979 level, and not statistically significant. Inclusion of time trends in the ROW variables in column (3) makes very little difference to these estimates. Of the time trends in the ROW variables, only that for remoteness is significant.

Table 3 is not estimated with heteroscedasticity-robust standard errors. Appendix Table A2 shows that, with robust standard errors, the *t*-statistics tend to be even larger than those

[6] This variable has a coefficient of one by construction.

shown in Table 3. Overall, these results paint a clear picture of a declining deterrent effect of transport costs on trade.

4.4 Alternative Specifications of the Dependent Variable

In this section we first re-estimate the FEVD regressions shown in Table 3 with the openness ratio as a straight percentage, and not in logarithms. The evidence in Coe *et al*. (2007) is that this changes the results dramatically for the time trend in transport cost effects in bilateral trade. We then consider the effects of imposing symmetry between the own-country transport cost coefficients and those of their respective multilateral resistance factors.

Table 4. FEVD Regressions for Openness (not in Logarithms), 1980-2005

Dependent variable: [100(X+M)/Y]			
Independent variables	(1)	(2)	(3)
ln (remoteness)	-11.36*** (-10.5)	-16.72*** (-7.74)	-17.10*** (-7.91)
ln (area)	-15.29*** (-85.7)	-17.17*** (-54.5)	-17.32*** (-53.8)
Landlockedness dummy	-11.06*** (-13.3)	-13.80*** (-8.66)	-13.26*** (-8.19)
ROW ln (remoteness)	-14.32** (-2.00)	-14.78** (-2.09)	8.65 (0.46)
ROW ln (area)	-8.38*** (-2.92)	-9.97*** (-3.51)	-18.00** (-2.55)
ROW Landlocked-ness dummy	-385.6** (-2.53)	-493.9*** (-3.27)	-72.4 (-0.16)
Freedom for trade	2.46*** (12.6)	2.37*** (12.2)	2.31*** (11.9)
ln (population density)	-10.27*** (-40.3)	-10.31*** (-40.9)	-10.33*** (-41.0)
Investment/GDP	1.55*** (37.5)	1.56*** (38.2)	1.56*** (38.2)
ln real per capita GDP	-1.74*** (-6.21)	-1.71*** (-6.17)	-1.66*** (-5.98)
ln terms of trade	4.86*** (6.04)	4.96*** (6.10)	4.87*** (5.98)
Time trend	0.879*** (17.5)	0.821*** (15.6)	0.755*** (13.1)
ln(remoteness)*time		0.341*** (2.77)	0.372*** (3.01)
ln(area)*time		0.132*** (7.07)	0.143*** (7.50)
Landlockedness dummy*time		0.193** (2.03)	0.158* (1.65)
ROW ln(remoteness)*time			-1.93 (-1.62)
ROW ln(area)*time			0.727* (1.64)
ROW Landlocked-ness dummy*time			-25.98 (-1.07)
Unidentified fixed effects	1.00*** (95.6)	1.00*** (97.0)	1.00*** (97.1)
Sample size	2214	2214	2214
R-squared	0.907	0.910	0.910
Standard error	12.16	12.00	11.96

Notes. Time=1 in 1980, =2 in 1981 etc. Figures in parentheses are *t*-statistics. *,**,*** denote significant at the 0.10, 0.05 and 0.01 levels respectively. The FEVD method is a three-stage procedure as described in Plümper and Troeger (2007). The results shown are from the third (pooled OLS) stage. “Unidentified fixed effects” are the residuals from a regression of estimated fixed country effects on the country-averaged variables in the model.

Table 4 shows that with this alternative transformation of the dependent variable we get very similar results to those shown in Table 3. In particular the own-country time trends are all positive, with significance levels similar to those shown in Table 3. The only variable not to have consistently the same sign as in Table 3 is the multilateral resistance factor for remoteness, which in columns (1) and (2) is now significant with the expected negative coefficient. The time trends in the coefficients of own-country remoteness and land area are both significant at the 1% level, and the time trend in the coefficient of own-country landlockedness is significant at the 10% or 5% level, depending on whether the multilateral resistance factor is included.[7] The similarity between Tables 3 and 4 stands in dramatic contrast to the results for bilateral trade, as demonstrated in Coe *et al*. (2007).

In the model of Baier and Bergstrand (2009), under the assumption of symmetrical (i.e. direction-independent) transport costs, the multilateral resistance factors are predicted to have coefficients that are equal and opposite in sign to the own-country variables. So far we have not imposed that assumption. In Table 5 we do so, by amalgamating the two into one variable: own-country minus ROW transport costs. There is very little difference between Table 5 and Table 3. The estimated time-trends in the transport cost effects are all positive and collectively highly significant, suggesting a declining deterrent effect on trade over time.

[7] We also get similar results using the logarithm of one plus the trade/GDP ratio as the dependent variable.

Table 5. FEVD Regressions with Symmetrical Effects

Dependent variable: ln[100(X+M)/Y]		
Independent variables	(1)	(2)
ln (remoteness) [own country minus ROW]	-0.331*** (-21.8)	-0.405*** (-13.3)
ln (area) [own country minus ROW]	-0.229*** (-95.4)	-0.263*** (-60.8)
Landlockedness dummy [own country minus ROW]	-0.190*** (-16.2)	-0.201*** (-8.94)
Freedom for trade	0.0597*** (21.6)	0.0583*** (21.4)
ln (population density)	-0.202*** (-56.5)	-0.203*** (-57.5)
Investment/GDP	0.0199*** (33.9)	0.0201*** (34.8)
ln real per capita GDP	-0.0620*** (-15.7)	-0.0613*** (-15.8)
ln terms of trade	0.0832*** (7.22)	0.0804*** (6.95)
Time trend	0.00944*** (15.9)	0.00806*** (12.7)
[OC-ROW ln(remoteness)] *time †		0.00469*** (2.68)
[OC-ROW ln(area)] *time †		0.00238*** (9.15)
[OC-ROW Landlockedness] *time †		0.00100 (0.75)
Unidentified fixed effects	1.00*** (80.0)	1.00*** (81.6)
Joint F-test of coefficients marked †		F(3, 2083) =34.46***
Sample size	2214	2214
R-squared	0.900	0.904
Standard error	0.1735	0.1703

Notes. Time=1 in 1980, =2 in 1981 etc. Figures in parentheses are *t*-statistics. *,**,*** denote significant at the 0.10, 0.05 and 0.01 levels respectively. The FEVD method is a three-stage procedure as described in Plümper and Troeger (2007). The results shown are from the third (pooled OLS) stage. "Unidentified fixed effects" are the residuals from a regression of estimated fixed country effects on the country-averaged variables in the model.

5) Conclusions

Transport costs are a significant factor in a country's ratio of international trade to GDP, because this ratio is an aggregation of bilateral trade flows to the country level. It follows that trade/GDP ratios can be used to investigate how transport cost effects in international trade have varied over time, which is a question that has proved hard to answer definitively using bilateral trade flows, where there are major heteroscedasticity issues.

Openness to international trade has increased significantly over time in the average country, which is itself suggestive of declining transport costs, although other factors, such as more liberal trade policies, may have contributed. Our results show that estimated transport cost effects, proxied by a country's GDP-weighted distance from others and by its land area, have declined over time; in other words countries with high values of these proxies for transport costs have experienced an increase in openness relative to those with low values, other things being equal. Our results are robust to the transformation of the dependent variable, in contrast to results obtained for bilateral trade flows. Our findings support the contention of Coe *et al*. (2007) that difficulties with the log-linear specification are responsible for the counter-intuitive result of bilateral trade studies that transport costs are becoming a stronger rather than a weaker deterrent to international trade over time.

As expected, countries with more liberal trade policies have higher trade ratios, and those that move to more liberal policies experience an increase in their trade ratios. Higher investment ratios, lower population density and better terms of trade are also associated with higher trade ratios.

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Appendix

This Appendix shows some additional regression results. In Table A1, fixed effect regressions similar to those shown in Table 2 are estimated with non-robust standard errors (and also without the ROW factors, whose omission makes little difference to the other coefficients). In Table A2, Table 3 is re-estimated with robust standard errors (the *t*-statistics are even larger if standard errors are clustered by country).

Table A1. Fixed Effect Regressions with Non-Robust Standard Errors

Dependent variable: ln[100(X+M)/Y]				
Independent variables	(1)	(2)	(3)	(4)
Freedom for Trade Index	0.0174*** (4.46)	0.0164*** (4.23)	0.0173*** (4.56)	0.0166*** (4.34)
Investment/GDP	0.0136*** (12.4)	0.0134*** (12.7)	0.0132*** (12.7)	0.0131*** (12.0)
ln real per capita GDP	0.119*** (4.59)	0.136*** (5.12)	0.104*** (4.08)	0.116*** (4.39)
ln terms of trade	0.0778*** (4.60)	0.0872*** (5.09)	0.0652*** (3.92)	0.0718*** (4.22)
Time trend	0.00961*** (12.0)	0.00925*** (11.4)	0.00690*** (8.15)	0.00665*** (7.46)
ln(remoteness)* time		0.00560*** (3.04)		000338* (1.85)
ln(area)*time			0.00260*** (8.80)	0.00249*** (8.44)
Landlockedness* time				0.000569 (0.39)
F-test of last three coefficients				F(3, 2102) = 15.6***
Sample size	2231	2231	2231	2231
No. of countries	121	121	121	121
F-test of country fixed effects	129.6***	129.6***	99.9***	100.0***
Standard error	0.1794	0.1790	0.1762	0.1761

Notes. Time=1 in 1980, =2 in 1981 etc. Figures in parentheses are *t*-statistics. *,**,*** denote significant at the 0.10, 0.05 and 0.01 levels respectively.

Table A2. Table 3 FEVD Regressions with Robust Standard Errors

Dependent variable: ln[100(X+M)/Y]			
Independent variables	(1)	(2)	(3)
ln (remoteness)	-0.335*** (-719.1)	-0.400*** (-985.0)	-0.403*** (-947.4)
ln (area)	-0.229*** (-2157.7)	-0.264*** (-3021.9)	-0.264*** (-2987.3)
Landlockedness dummy	-0.197*** (-438.3)	-0.211*** (-520.0)	-0.212*** (-509.1)
ROW ln (remoteness)	0.511*** (118.9)	0.492*** (154.8)	1.14*** (126.7)
ROW ln (area)	0.0916*** (84.7)	0.0675*** (71.9)	-0.0427*** (-40.4)
ROW Landlocked-ness dummy	-6.97*** (-81.4)	-8.55*** (-113.9)	-12.59** (-141.6)
Freedom for trade	0.0612*** (547.0)	0.0605*** (600.2)	0.0606*** (582.9)
ln (population density)	-0.202*** (-1857.1)	-0.202*** (-2007.7)	-0.202*** (-1985.8)
Investment/GDP	0.0201*** (344.1)	0.0202*** (360.9)	0.0201*** (361.0)
ln real per capita GDP	-0.0637*** (-350.3)	-0.0637*** (-405.6)	-0.0634*** (-393.2)
ln terms of trade	0.0844*** (9.05)	0.0799*** (8.56)	0.0811*** (8.69)
Time trend	0.0097*** (243.8)	0.0082*** (157.2)	0.0074*** (120.7)
ln(remoteness)*time		0.0041*** (18.3)	0.0044*** (19.9)
ln(area)*time		0.0025*** (108.6)	0.0025*** (101.7)
Landlockedness dummy*time		0.0010*** (7.61)	0.0010*** (7.61)
ROW ln(remoteness)*time			-0.0430*** (-79.6)
ROW ln(area)*time			0.0082*** (39.3)
ROW Landlocked-ness dummy*time			0.183*** (33.2)
Unidentified fixed effects	1.00*** (1872.9)	1.00*** (2013.9)	1.00*** (1940.4)
Sample size	2214	2214	2214
R-squared	0.900	0.904	0.904
Standard error	0.1733	0.1700	0.1696

Notes. Time=1 in 1980, =2 in 1981 etc. Figures in parentheses are heteroscedasticity-robust *t*-statistics. *,**,*** denote significant at the 0.10, 0.05 and 0.01 levels respectively.