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The Distance Puzzle: On the Interpretation of the Distance Coefficient in Gravity Equations

by

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Abstract

Globalization seems to have diminished the importance of geographical distance. However, empirical studies find that distance coefficients in gravity equations change little over time. This paper argues that changes in distance coefficients do not carry much information on changes in distance costs over time. Changes in distance costs are to a large extent picked up solely in the constant term of gravity models. The distance coefficient instead measures the relative difference between far way and close countries. A proportional fall in distance costs that leads to a proportional increase in economic activity would be consistent with constant distance coefficients.

Keywords: distance coefficients, gravity equations, globalization

JEL-Classification: F0, F21

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1 Motivation

The globalization of the world economy seems to have diminished the economic importance of geographical distance. Technological improvements have potentially facilitated the integration of markets through two channels. First, information technology has improved and has eased access to information about foreign countries and foreign partners. Second, technological improvements ease economic integration because they lower shipping costs. Moreover, impediments to the integration of markets in the form of tariff and non-tariff barriers have been abolished on a large scale. As a consequence, 'distance costs' can be expected to have declined, and one would expect national markets to move closer together and distance to become less important over time.[1] Hence, lower distance costs are likely to be behind the sharp increase in gross trade, capital, or migration flows that characterize the globalization process.

Directly assessing the importance and the effects of a decline in distance costs for the globalization process is problematic though because we can typically not measure distance costs directly. Attempts to measure transportation cost changes

[1] In fact, economic theory would predict that lower costs of international transactions increase the volume of trade, of capital flows, or of labor migration. Kleinert and Schuknecht (2003) survey literature which analyzes the impact of transactions costs in models of international trade and FDI. Modelling the impact of distance and of other transactions costs on international capital flows is a relatively recent strand of the literature (see, e.g., Martin and Rey 2001). Cultural factors, that could be related to distance, are also a key ingredient of theoretical migration models (Gross and Schmitt 2000).

directly as the spread between f.o.b. and c.i.f. prices is typically not very helpful. This spread often turns out to be negative, although this would imply that transportation costs are negative (Gehlhar and McDougall 2000). Hence, empirical work typically uses geographic distance as a proxy for transportation costs (see Table 1). More specifically, gravity equations specify the log of bilateral trade, FDI, or capital flows as a function of log distance, log GDP, and a set of control variables. Many of these studies find that the coefficient on distance remains unchanged when comparing cross-section estimates for different time periods. This result seems all the more puzzling since anecdotal evidence (Cairncross 1997) and direct measures of distance costs (World Bank 1995) suggest that actual distance costs have fallen.

The rather unchanged distance coefficients which are derived by many cross-section regressions seem to fly in the face of the logic that technological change and deregulation of markets, i.e., the globalization process, should have diminished the importance of distance. Several possible explanations for this puzzle have been ventured. One line of defense has been to control for other factors that might capture deregulation and technological change. Freund and Weinhold (2000) control for the importance of the use of the internet, but the distance coefficients remain rather stable. Brun et al. (2002) likewise control for omitted

Table 1 — Selected Previous Empirical Results

Paper	Specification	Dependent variable	Explanatory variables	Coefficient on distance
Boisso and Ferrantino (1997)	tobit regression 1960-1985, developing and developed countries	log bilateral exports	host and source country GDP (and GDP per capita), geographic distance, openness, linguistic similarity	–1.31 (1960), –1.29 (1985), results do not differ much across specifications
Bougheas et al. (1999)	SUR and IV-SUR regressions 1970-1990, EU and Scandinavia	log bilateral exports	host and source country GDP, stock of public capital, length of motorway network, distance, adjacency dummy	–0.72 to –0.78
Djankov and Freund (2002)	Cross-section regressions 1987-1996, Russian regions	log bilateral trade	host and source region GDP, host and source region population, bilateral distance, dummy for intra-Russian trade	–0.42 (1987),
Egger (2000)	Fixed effect panel regressions OECD countries, 1985-1996	log bilateral trade	relative factor endowments, distance	–1.08 to –1.23
Egger (2002)	Panel regressions OECD and 10 transition economies, 1986-1997	log bilateral exports	GDP, country size, difference in relative factor endowments, legal variables, distance, common border, common language	–0.18 (between estimator) to –0.915 (random effects estimator)
Frankel (1997)	63 countries, 1965-1992	bilateral trade	GNP, GNP per capita, distance, common border, common language, free trade arrangements	–0.4 (1965) and –0.7 (1992)
Frankel and Rose (2000)	OLS and panel regressions 186 countries for the years 1970-1995	log bilateral trade	real GDP, real GDP per capita, common language, common border, common free trade arrangement, common colonizer, political union, number of landlock in pair, number of islands in pair, land area, currency union dummy	–1.1
Freund and Weinhold (2000)	cross-section regressions for the years 1995–1999 for 56 countries	log bilateral trade	GDP, population, distance, adjacency dummy, language, number of internet hosts	–0.89 (1995) and –0.82 (1999)

Table 1 continues …

… Table 1 continued.

Paper	Specification	Dependent variable	Explanatory variables	Coefficient on distance
Leamer (1993)	percent of trade between adjacent countries, geographic concentration of trade ('half-distance') 1970, 1985, OECD countries	levels and logs of bilateral trade	distance, real wages	distance has important impact, little change in importance of distance over time
Porojan (2001)	EU and 7 OECD countries 1995	Log bilateral exports and imports	GDP, distance	–0.996 to –0.592 for exports –1.02 to –0.55 for imports
Portes and Rey (2001)	panel and cross-section regressions 1989-1996, 14 OECD countries	Log bilateral equity flows log bilateral trade	market capitalization, degree of investor sophistication, volume of telephone calls, proxies for insider trading, distance, exchange rate stability dummy, covariances between GDP growth rates	–0.54 (1989) and –0.71 (1996) for equity flows –0.23 for foreign trade if information variables included
Wei (2000)	fixed and random effects panel regressions FDI from 13 source to 30 host countries, bank lending from 13 lending to 83 borrowing countries, averages for 1994-96	Log bilateral FDI and bank lending	measure of corruption, GDP, GDP per capita, distance, linguistic ties	–0.54 to –0.97 (FDI) –0.23 to –0.77 (bank lending)
Wolf (2000)	OECD countries 1985-1996	Log international and interstate bilateral exports	GDP, distance, measure of remoteness, dummy for intrastate trade	– 1.25 to – 1.49

variables such as trade restrictions, and this partly helps to resolve the puzzle. Including these regulatory factors lessens the impact of distance but does not fully override it.

This paper tackles the issue from a more conceptual angle. Do constant distance coefficients in cross-section regressions really imply that distance costs have not fallen? We argue that little can actually be learned with regard to changes in distance costs from comparing distance coefficients for different time periods. Changes in distance costs are to a large extent picked up solely in the constant term of gravity models specified in logs and are thus confounded with a number of other factors that might have changed over time. The distance coefficient instead measures the relative importance of economic relationships between the source countries and host countries that are located far away as opposed to those located closely to the source countries (Frankel (1997) has made this point). If distance costs shrink for all countries proportionally, no change in the coefficient would be observable.

The paper is structured as follows. In the following Part Two, we summarize earlier evidence on distance coefficients, which mainly focuses on foreign trade, and we provide new empirical evidence, which is based on German firms' foreign direct investments. In Part Three, we lay down the conceptual argument why the interpretation of coefficients on geographical distance as evidence in favor or against changes in 'distance costs' is problematic. Part Four concludes.

2 Empirical Evidence

Before discussing the interpretation of distance coefficients in empirical gravity equations, it is useful to briefly review the literature using these models. We begin by reviewing the evidence on international trade, then we turn to new empirical evidence on international investment decisions.

2.1 International Trade

According to the gravity model of foreign trade, trade between two countries is proportional to the size of the markets, and it is inversely related to geographical distance.[2] Table 1 gives an overview of earlier empirical work using gravity-type models. (For surveys see also Frankel (1997) or Leamer and Levinsohn (1995).) Whereas the traditional foreign trade literature has interpreted the distance coefficient as evidence for the presence of physical transportation costs (see, e.g., Freund and Weinhold 2000), Portes and Rey (2001) argue that distance affects bilateral economic relationships also through its impact on information costs.

A few papers look at changes of distance coefficients over time. Results by Frankel (1997) for international trade suggest that the distance coefficient has increased in absolute terms from –0.4 in 1965 to –0.7 in 1992. He notes that interpretation of the fall in distance coefficients as a fall in distance costs is prob-

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[2] See Anderson and Wincoop (2001), Deardorff (1998), or Feenstra, Markusen and Rose (2001) for theoretical underpinnings.

lematic. We will pick up this argument below (Section 3) in a more formal framework. Freund and Weinhold (2000) use cross-section data for the years 1995 through 1999 and find a relatively constant coefficient on distance of –0.8 even if they control for the possible impact of the internet on trade. In a case study of the Former Soviet Union, Djankov und Freund (2002) find that the importance of distance has become more important, the coefficient increasing in absolute terms from –0.42 in 1987 to –1.17 in 1996.

In terms of interpretations of the (unchanged) distance coefficients, Boisso and Ferrantino (1997) and Brun et al. (2002) explicitly argue that falling costs of international transactions would be expected to show up in a declining distance coefficient. Similarly, Freund and Weinhold (2000) interpret the stable relationship between distance and trade as evidence for the continued importance of transportation costs. Brun et al. (2002) argue that the increasing importance of distance which some empirical studies find might be due to the fact that some important variables (quality of infrastructure, changes in trade policy, freight costs, structure of exports) have been excluded. Including these variables leaves the distance coefficient unchanged.

2.2 International Investment Decisions

More recently, the gravity equation has also been used to study the determinants of international investment decisions. In a study on international equity flows, Portes and Rey (2001) use cross-section regressions for each of the years 1989 through 1996 which show that the magnitude of the distance coefficient has remained virtually unchanged. Buch (2002) obtains a similar result for international banking assets and liabilities.

Table 2 presents new empirical evidence which shows that a constant distance coefficient can not only be found in empirical models of foreign trade, international equity flows, or bank lending but also for foreign direct investments (FDI). We use data on the stocks of FDI by German firms abroad to estimate gravity equations for each of the years 1990–2000. (For details on the database and the specification of the empirical gravity equation see also Buch, Kleinert, and Toubal (2003)).

Results show a positive link between FDI of German firms and host-country GDP and a negative effect of GDP-per-capita. We additionally control for regulations and risk, and we include proxies for information costs. We find that sharing a common border and a common language seems to increase the levels of FDI. High risk, as captured through a measure of country risk and an index of economic freedom, lowers FDI. The effect of convertibility restrictions is ambiguous: while capital controls lower FDI, multiple exchange rate regimes tend to have a positive impact. An EU dummy has a positive effect only for the first years under study.

Table 2 — Cross Section Regressions for German FDI

OLS estimates. Dependent variable (FDI). The explanatory variables GDP, GDP per capita, and distance are in logs. *, **, *** significant at 10%, 5%, and 1% level, respectively. *GDP* and GDP per capita are measured in dollar and were taken from the World Development Indicator (2002). Distance is the great-circle distance between the two latitude-longitude combinations, *border* is a dummy which is equal to 1 for neighboring countries, *risk* is the Euromoney composite country risk measure (where a higher index indicates lower country risk), *freedom* is the index of economic freedom of the Heritage Foundation (where a higher index indicates a lower degree of economic freedom), *capital* and *xexch* were taken from the IMF Annual Report on Exchange Arrangements and Exchange Restrictions. *Capital* is a dummy which is one if the country has capital controls in place, *xexch* is a dummy which is one if the country has multiple exchange rates, *eu* is a dummy which is equal to one for EU countries, and *comlang* is a dummy which is equal to one if German is the official language in the host country. Regression includes income dummies and sectoral dummies.

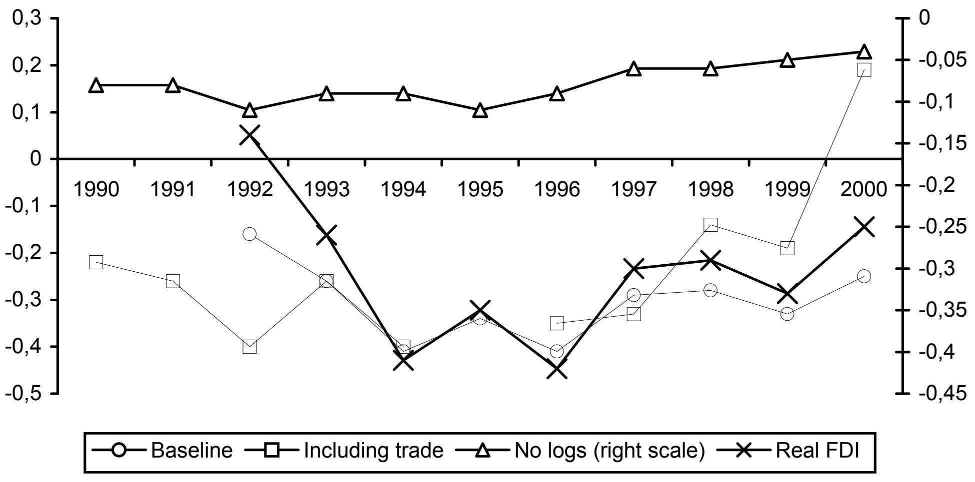
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
gdp	0.63***	0.62***	0.58***	0.58***	0.61***	0.63***	0.64***	0.72***	0.69***	0.70***	0.69***
	(11.20)	(10.34)	(10.63)	(11.67)	(12.44)	(14.24)	(14.49)	(16.11)	(17.69)	(16.88)	(16.73)
gdpcap	–1.17***	–0.76***	–0.70***	–0.29	–0.68***	–0.38*	–0.04	–0.28	–0.45***	–0.89***	–0.57***
	(–4.03)	(–2.98)	(–3.10)	(–1.27)	(–3.08)	(–1.89)	(–0.22)	(–1.56)	(–2.64)	(–5.78)	(–3.40)
distance	–0.01	0.00	–0.16**	–0.27***	–0.41***	–0.35***	–0.41***	–0.29***	–0.29***	–0.33***	–0.25***
	(–0.07)	(0.00)	(–2.11)	(–3.34)	(–5.63)	(–5.44)	(–6.29)	(–4.83)	(–4.67)	(–5.64)	(–4.05)
border	0.45*	0.61**	0.31	0.02	–0.08	0.17	0.07	0.41**	0.69***	0.49***	0.49**
	(1.79)	(2.23)	(1.24)	(0.07)	(–0.37)	(0.82)	(0.31)	(2.13)	(3.34)	(2.61)	(2.26)
risk	0.66*	0.85**	1.29***	1.23***	0.94***	1.51***	1.18***	1.23***	1.09***	2.03***	1.79***
	(1.82)	(2.47)	(3.91)	(3.63)	(2.78)	(4.72)	(3.09)	(3.15)	(4.25)	(5.20)	(4.42)
freedom	–0.15***	–0.15***	–0.24***	–0.25***	–0.29***	–0.20***	–0.16***	–0.16***	–0.18***	–0.15***	–0.16***
	(–2.98)	(–3.31)	(–4.69)	(–5.26)	(–5.96)	(–4.34)	(–3.15)	(–3.88)	(–4.58)	(–4.04)	(–4.41)
capital	–0.29	–0.02	–0.61***	–0.78***	–0.87***	–0.59***	–0.28*	–0.18	0.25	–0.14	–0.01
	(–1.61)	(–0.11)	(–3.34)	(–3.59)	(–4.55)	(–3.67)	(–1.73)	(–1.03)	(1.38)	(–0.70)	(–0.03)
xexch	–0.49**	0.19	0.50**	0.59***	0.28	0.47**	0.49***	–0.29	0.50	0.41	–0.31
	(–2.03)	(0.89)	(2.54)	(2.98)	(1.44)	(2.41)	(2.66)	–0.65	(1.05)	(1.26)	(–0.93)
eu	0.59*	0.93***	0.33	–0.05	–0.17	0.20	–0.26	0.53	0.88	–0.08	1.01
	(1.95)	(2.94)	(1.59)	(–0.17)	(–0.51)	(0.28)	(–0.37)	(0.83)	(1.34)	(–0.42)	(1.63)
comlang	1.01***	0.82***	1.26***	0.99***	0.99***	0.66***	0.60***	0.64***	0.33	0.66***	0.59**
	(3.70)	(3.11)	(5.29)	(3.80)	(4.38)	(3.07)	(2.66)	(2.76)	(1.39)	(2.82)	(2.47)
R^2	0.58	0.56	0.55	0.55	0.57	0.57	0.55	0.58	0.56	0.57	0.54
N	798	824	902	959	1010	1074	1120	1145	1182	1174	1236

On average, we find a distance coefficient of around –0.3. This coefficient has, in addition, stayed relatively constant over time. Whereas the impact of distance has been insignificant in the first two years of our sample period (1990–1991), it has increased somewhat in absolute terms through the mid-1990s to –0.4, and settled at a value of around –0.25 towards the end of the decade. Wald tests also confirm that changes in the point estimates over time have been insignificant (results are not reported but are available upon request).

Moreover, the results are fairly robust against changes in the specification of the model as long as we keep the logarithmic form. As revealed by Graph 1, we obtain relatively constant distance coefficients also for a specification in which trade is included (instrumented through lagged trade), and for a specification which uses real FDI as the dependent variable.

Graph 1 — Changes in Distance Coefficients 1990–2000

This graph plots the distance coefficients obtained from (i) a baseline OLS regression of FDI (including income dummies, sectoral dummies; data are in logs), (ii) an IV-regression including trade, (iii) a baseline regression with variables not being entered in logarithmic form, and (iv) a baseline regression with real FDI, using the consumer price index to deflate the stock of German FDI to constant US dollars). For specification (iii), beta-coefficients are reported.



3 Distance Coefficients versus Distance Costs

In this section, we show that the interpretation of changes in distance coefficients in cross-section gravity models in terms of changes in distance costs over time is mis-leading. Greater integration of markets as a consequence of falling distance costs is rather picked up in the constant term of empirical gravity models.

3.1 Distance Costs and Increased Integration

We presents a simple example which shows that that bilateral economic relationships — and thus the degree of economic integration — might increase due to falling distance costs while estimated distance coefficients remain unchanged. We assume that bilateral economic relationships between country *i* and a number of partner countries *j* (Y_{ij}) are, as in standard gravity models, a function of only two variables: *GDP* of country *j,* and the geographic distance ($Dist_{ij}$) between the two countries. Some unobservable variables are "collected" in the constant term. Bilateral economic relationships are specified in a general form and can represent bilateral trade, capital flows, or migration. The estimated equation has two regressors and a constant:

$$\ln(Y_{i,j}) = \beta_0 + \beta_1 \ln(GDP_j) + \beta_2 \ln(Dist_{i,j}) + u_{i,j} \qquad (1)$$

where $u_{i,j}$ is the residual. This logarithmic specification is the econometric specification generally used (see also Table 1). Equation (1) assumes that distance costs (*DC*) (i.e. fixed or variables costs of entry in the form of regulations, tariffs, transportation costs, or information costs) are not readily observable. Hence, the assumption which underlies this specification is that distance costs are a linear function of geographical distance $DC = f\left(Dist_{i.j}\right) = k \cdot Dist_{i,j}$. Bilateral economic relations and the degree of integration of countries, in turn, are inverse proportionally to distance costs, i.e. $Y_{i,j} = f(1/DC)$. Hence, lower distance costs, as reflected in a decline in *k*, would increase the degree of integration.

However, proportional changes in distance costs, which lead to a proportional change in $Y_{i,j}$, do not affect the point elasticity of distance in cross-section equations. This holds irrespective of the fact whether distance costs are measured directly or indirectly (through geographic distance). Hence, changes in the distance coefficient cannot be interpreted as evidence for or against changes in distance costs. To see that the point elasticity of distance is unaffected by a change in the parameter *k*, note that in standard OLS-model, β_1 and β_2 are calculated as:

$$\begin{pmatrix} \hat{\beta}_1 \\ \hat{\beta}_2 \end{pmatrix} = \begin{bmatrix} \sum\left(gdp_j\right)^2 & \sum gdp_j dist_{i,j} \\ \sum gdp_j dist_{i,j} & \sum\left(dist_{i,j}\right)^2 \end{bmatrix}^{-1} \begin{bmatrix} \sum gdp_j y_{i,j} \\ \sum dist_{i,j} y_{i,j} \end{bmatrix} \tag{2}$$

where a upper bar variables denote the mean and small cases denote deviations from the mean of the logs of the exogenous and endogenous variables. Solving this system of equations gives

$$\begin{pmatrix}\hat{\beta}_1 \\ \hat{\beta}_2\end{pmatrix} = \frac{1}{\Delta}\begin{bmatrix} \sum\left(dist_{i,j}\right)^2 & \sum gdp_j y_{i,j} - \sum gdp_j dist_{i,h} & \sum dist_{i,j} y_{i,j} \\ -\sum gdp_j dist_{i,j} & \sum gdp_j y_{i,j} + \sum\left(gdp_j\right)^2 & \sum dist_{i,j} y_{i,j}\end{bmatrix} \quad (3)$$

with $\Delta = \sum\left(gdp_j\right)^2 \sum\left(dist_{i,j}\right)^2 - \left(\sum gdp_{i,j} dist_{i,j}\right)^2$

The constant β_0 is calculated as

$$\beta_0 = \overline{y}_{i,j} - \beta_1 \overline{gdp}_j - \beta_2 \overline{dist}_{i,j} . \quad (4)$$

Now, let the parameter *k* decline over time such that *DC* in $t = 1$ is only a fraction of the distance costs in $t = 0$. Thus, geographic distance does not change but distance costs decrease to $1/\lambda$ of the level of distance costs in $t = 0$. The change is assumed to be proportional across all partner countries since $k_1 = k_0 / \lambda$. For simplicity, suppose the GDP of each partner country *j* to be constant over the time period analyzed.[3]

Due to the decline in distance costs, the level of bilateral economic cross-border activity $Y_{i,j}$ changes but, if equation (1) is specified in logs, the deviation of y from its mean, $\bar{y}$, does not change ($y_{DClow} = y_{DChigh}$). If the value of all bilateral relationships increases by the same rate, say 1-%, the deviation from the mean remains the same. Hence, β_1 and β_2 do not change, although distance costs have decreased drastically. However, the mean of $\bar{y}$ increases

[3] Relaxing this assumption would not change the results of the following argument.

($\bar{y}_{DClow} > \bar{y}_{DChigh}$). This increase in the mean would be reflected in an increase of the constant term β_0.

Results for our empirical example of German firms' FDI that was reported in Section 2.2 confirm these considerations (results are not reported but are available from the authors upon request). As a test of whether the estimated distance coefficient has changed in importance over time, we include interaction terms between dummies for each year and distance in a quasi-*ij*-panel. None of these interaction terms is significant, which suggests that the impact of distance on the regional pattern of German FDI has not changed over time. Just as at the beginning of the 1990s, a 10% increase in distance at the end of the 1990s led to a 3% decrease in FDI. At the same time, we do find that the time dummies have increased in absolute terms over time, which shows the increase in the absolute level of German firms FDI over time.

These considerations do not change qualitatively if equation (1) is set up in levels. If the regression is set up in levels instead of logs and if the endogenous variable increases proportionally because of a decrease in distance costs, both the mean and the deviation from the mean increase, since the deviation is now measured in absolute terms and not in percentage of the mean. Hence, β_1 and β_2 change, although the regressors GDP_j and $Dist_{i,j}$ do again not change. Both coefficients would increase in absolute terms with falling distance costs and rising levels of the endogenous variable. However, the *rising* (absolute value of the negative) distance coefficient β_2 results from *falling* distance costs.

Again, we find support for this argument in our example of German FDI. Estimating the determinants of the level of firms' FDI shows that, at the beginning of the 1990s, an increase in distance by one unit lowered FDI by 7.1 units. At the end of the 1990s, the one-unit increase in distance reduced FDI by 17.1 units. This reflects the strong increase in German outward FDI over this decade. The Beta-coefficient of distance falls over the decade. While it stood at about -0.09 at the beginning of the nineties, it fell (in absolute terms) to –0.05 at the end (Graph 1).

3.2 A Numerical Example

A numerical example might clarify the point further. It shows that the distance coefficient might remain unchanged even if distance costs decline significantly. As an illustration of the above argument, consider the example of bilateral exports of an hypothetical country which is given in Table 3. We consider two time periods. In the first period, distance costs are eight times higher than those in the second period, i.e. we set $\lambda = 8$. *GDP* remains constant over time. The hypothetical dataset assumes that exports decline in distance costs. They are eight times larger in the second period compared to the first period for each country pair. Thus, the change in distance cost leads to an (proportional) increase in all export values. All exogenous variables remain unchanged.

Table 3 — A Numerical Example

$Y_{DC\ high}/Y_{DC\ low}=1/k=8$, $y_{DC\ high}$, $y_{DC\ low}$ logarithmic endogenous variable given in deviation from the mean.

n	$Y_{DC\ high}$	$Y_{DC\ low}$	*GDP*	*Distance*	$ln(Y_{DC\ high})$	$ln(Y_{DC\ low})$	$y_{DC\ high}$	$y_{DC\ low}$
1	6.75	54.00	15	7.5	1.91	3.99	0.55	0.55
2	5.70	45.60	14	9.0	1.74	3.82	0.38	0.38
3	5.31	42.48	13	8.3	1.67	3.75	0.31	0.31
4	6.36	50.88	12	2.8	1.85	3.93	0.49	0.49
5	4.20	33.60	11	8.0	1.44	3.51	0.08	0.08
6	3.12	24.96	10	9.6	1.14	3.22	–0.22	–0.22
7	4.02	32.16	9	4.6	1.39	3.47	0.03	0.03
8	3.00	24.00	8	6.0	1.10	3.18	–0.26	–0.26
9	3.42	27.36	7	2.6	1.23	3.31	–0.13	–0.13
10	2.61	20.88	6	3.3	0.96	3.04	–0.40	–0.40
11	1.71	13.68	5	4.3	0.54	2.62	–0.82	–0.82
Mean	4.2	33.6	10	6	1.36	3.44	0	0

Using the data of Table 3, estimations of a log specification of equation 1 yields:

$$Ex_{i,j}^{0} = -1.12 + 1.38 * GDP_j - 0.36 * Dist_{i,j} \quad \text{for } t = 0 \qquad (5)$$
$$(-10.7)(24.4) \qquad (-8.7)$$

and

$$Ex_{i,j}^{1} = 0.96 + 1.38 * GDP_j - 0.36 * Dist_{i,j} \quad \text{for } t = 1.$$
$$(9.2)\ (24.4) \qquad (-8.7)$$

The *t*-values are given in parenthesis. The R^2s of the regressions are very high (0.99), because we use a constructed dataset without any error component.

Although distance costs *DC* have increased by the factor eight, this does not show up in the distance coefficient (β_2), which gives the partial effect of distance on exports, but rather in the constant term. The correct interpretation of the distance coefficient is that a 10% increase in distance between the two trading partners lowers exports by 3.6%. This effect has remained unchanged over time. However, it cannot be concluded that (unmeasured) distance costs have not changed over the same period or that the change in distance costs has had no effect on exports. Rather, falling distance costs have had a tremendous effect on export levels, which increase by a factor of eight. However, this strong increase can be seen in the constant term (β_0) only.

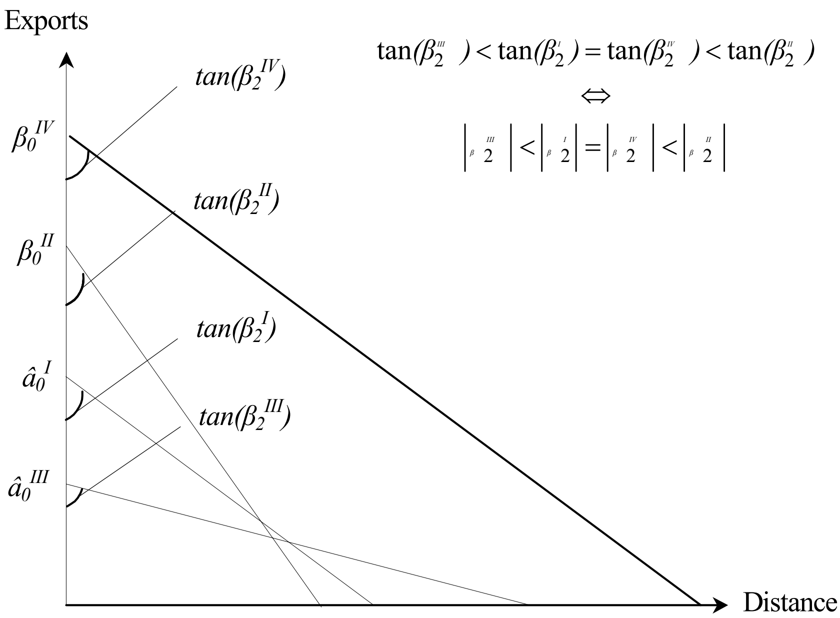
Hence, the coefficient β_2 can be a misleading measure to judge how the effect of distance costs on exports has changed when comparing two cross-section regressions applying to two points in time. The change in β_0 would be the right measure but, being the constant of the regression, both effects of distance costs and those other omitted variables might be included in this coefficient. Note, in addition, that including additional explanatory variables would not change this conclusion.

3.3 Robustness of Results

It could be objected that the above argument does not generalize to cases where distance costs change in a non-proportional way or to cases where other variables change as well. Even if these modifications were taken into account though, the main qualitative result of the argument would remain unchanged.

Graph 2 depicts the effect of distance and distance costs on bilateral economic relationships such as exports. Four cases are illustrated which differ in total export levels and the distribution of these exports over the different distances. In each of the cases, changes in the average level of exports are reflected by changes in the intercept while changes in the slopes reflect changes in the elasticity of exports with respect to distance costs.

Graph 2 — Proportional Versus Non-Proportional Distance Cost Changes



Using case I as the benchmark, three scenarios are distinguished:

In scenario 1, distance costs decrease proportionally from I to IV. In this case, the elasticity of exports with respect to distance and thus the distance coefficient β_2 remains unchanged. All information about the positive effect of decreasing distance costs on *Exports* is contained in the constant β_0^{IV} which is larger than the constant β_0^{I}.

In scenario 2, distance costs decrease non-proportionally from I to II, and the decrease is greater for smaller distances. Now, the distance coefficient β_2^{II} is larger (in absolute terms) than β_2^{I}. Export levels are higher for small distances in II than in the benchmark I, but they are lower for large distances.

In scenario 3, distance costs also decrease non-proportionally from I to III, but now the decrease is smaller for smaller distances. The distance coefficient β_2^{III} is now smaller than β_2^{I} in absolute terms. In case III, export levels are smaller for close distances but larger for long distances as compared to the benchmark I. Note that for both scenarios of non-proportional changes, from I to II and from I to III, the total effect of distance on exports depends always on β_0 and β_2. Thus, changes in β_2 alone reflect the effect of distance on exports only incompletely.

Next, consider the case in which other variables – such as GDP – change over time but distance costs do not. The assumption of a change of GDP across all partner countries does not affect our argument since, on average, this does not affect the marginal distance coefficient. However, in empirical studies changes of GDP might have an effect on the distance coefficient if the two variables are not completely statistically independent. But that is nothing conceptual. The problem is rather that changes of other variables are, at least partly, also reflected by a change of the constant. It is therefore impossible to use the constant as a measure of distance costs change. With more exogenous variables than distance costs changing, the constant does not only hold information about the change of distance costs as in the example above.

3.4 What Does the Distance Coefficient Measure?

The fact that changes in the distance coefficient over time cannot be interpreted in terms of rising or falling distance costs does not render the interpretation of this coefficient meaningless, of course. Rather, β_2 does measure how important bilateral economic relationships are with partners that that are far away relative to those with partners that are close to the home country. Hence, changes in β_2 over time the indicate changes in the relative importance of far-away and nearby countries. A decrease of β_2, (in absolute terms) for instance, indicates that trade with countries far away increases relative to trade with countries closer to the home country. One reason for such an asymmetric change could be improvements in air transportation technology because a large fraction of costs in this industry are unaffected by distance. An increase of β_2, in contrast, indicates that trade with countries far away decreases relative to trade with countries closer to the home country. An example for such a non-proportional change could be the integration process taking place in Europe. More specifically, the deepening of the EU integration process has tended to stimulate bilateral economic relationships among the EU countries, i.e. among countries located within a relatively close regional reach.

4 Conclusion

Increasing volumes of global trade and capital flows are indicators of the globalization of the world economy. Deregulation and technological progress are likely to have lowered the costs of bridging large distances and to have led to a decline in 'distance costs'. Beyond this conventional wisdom, economists are interested in empirically assessing the magnitude of these changes. Since direct measures of distance costs are often unavailable, geographic distance between countries is often used as a proxy. Many applications of gravity equations suggest that the coefficient on distance has not changed significantly over time, and this could be taken as evidence against declining distance costs.

In this paper, we have argued that this interpretation of distance coefficients is mis-leading. Essentially, we cannot infer changes in distance costs from changes in distance coefficients obtained from cross-section equations for different years. In the extreme case of a proportional decline in distance costs and a proportional increase in bilateral economic linkages, the effects of changes in distance costs would show up solely in the constant term of gravity equations.

These considerations do not imply, of course, that distance coefficients are uninformative with regard to globalization trends. Falling distance costs do have caused a strong increase in international activities of all kinds. Hence, the often pro-claimed 'death of distance' has not occurred, and distance is still an important determinant of international economic activity. However, the correct interpretation of constant distance coefficients is that international activities between countries that are located far away from each other and between countries that are located close to each other have expanded at similar proportions.

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