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Infrastructure, Geographical Disadvantage and Transport Costs

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Abstract:

We use several different data sets to investigate the dependence of transport costs on geography and infrastructure. Poor infrastructure accounts for 40% of predicted transport costs for coastal countries and 60% for landlocked. Landlocked countries can substantially reduce their high transport costs through improvements in own and transit countries' infrastructure. Analysis of bilateral trade data confirms the importance of infrastructure and gives an estimate of the elasticity of trade flows with respect to the trade cost factor of around -3. This means that raising trade costs by 10 percentage points reduces trade volumes by more than 20%. A deterioration of infrastructure from the median to the 75th percentile raises transport costs by 12% points and reduces traded volumes by 28%. Analysis of African trade flows indicates that their relatively low level is largely due to poor infrastructure.

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1. Introduction

The real costs of trade – the transport and other costs of doing business internationally – are important determinants of a country's ability to participate fully in the world economy. Remoteness and poor transport and communications infrastructure isolate countries, inhibiting their participation in global production networks.[1] For example, landlocked countries on average in 1995 had an import share in GDP of 11%, compared to 28% for coastal economies; of the top 15 non-primary export performers in 1965-1990, eight are island and none are landlocked countries.[2] As liberalization continues to reduce artificial trade barriers the effective rate of protection provided by transport costs is now, in many cases, considerably higher than that provided by tariffs.[3] To bring countries further into the trading system it is important to understand both the determinants of transport costs, and the magnitude of the barriers to trade that they create. Investigation of these issues is our goal in this paper.

We study the determinants of transport costs and show how they depend both on countries' geography, and on their levels of infrastructure. The importance of geography has been established in recent work by Hummels (1998b), as well as in an older literature (Moneta 1959)[4]. The geographical measures we focus on are distance between countries, whether they share a common border, and whether they are landlocked or are islands. The infrastructure measures relate to the quality of transport and communications infrastructure. Although the importance of infrastructure for transport costs is well established in regional and transport economics, the few empirical studies of international transport costs often neglect this and focus on geographical and product characteristics. [5] We show that infrastructure is quantitatively

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[1] Increasing trade in components and the geographical fragmentation of some production processes make transport costs even more important. See Feenstra (1998) and the references quoted therein for evidence of the increase in the importance of intermediate goods trade. Radelet and Sachs (1998) show how sensitive value added is to transport costs in a vertically fragmented activity.

[2] World Bank Development Indicators. Export performance corresponds to non-primary manufactures products export growth between 1965-1990 from Sachs and Radelet (1998), table I.

[3] See Finger and Yeats (1976) for U.S. Post-Kennedy Round data on nominal and effective rates of protection afforded by tariffs and transport costs . See Hummels (1998b) for recent data on nominal rates for the U.S., New Zealand, Argentina and Brazil.

[4] Hummels (1998b) has undertaken a thorough study of the implications of geography for freight rates on commodity disaggregated imports of the US, New Zealand and 5 Latin American countries.

[5] An exception to this is Radelet and Sachs (1998) where port quality is entered as an explanatory variable for transport costs.

important in determining transport costs, a finding with important policy implications for infrastructure investment. Poor infrastructure accounts for 40% of predicted transport costs for coastal countries, and up to 60% for landlocked countries. An improvement in own and transit countries' infrastructure from the 25th percentile to the 75th percentile overcomes more than half of the disadvantage associated with being landlocked.

Our research uses several different sources of transport cost data. The first is shipping company quotes for the cost of transporting a standard container from Baltimore to selected destinations. The advantages of this measure are that it is the true cost of transporting a homogenous good, and that it gives both the city of landfall and the final destination city. This enables us to compare the transport costs of land and sea legs of a journey, finding that the former is around seven times more costly per unit distance. The disadvantage of this data set is that it is not clear how the experience of Baltimore generalizes, since charges are affected by the particular routes, frequencies, opportunities for back-hauling and for exploiting monopoly power that are present. Our second data set uses a cross-section of the cif/ fob ratios reported for bilateral trade between countries by the IMF. These are representative, in so far as they cover the entire imports of each reporting country. However, the measure is an aggregate over all commodity types imported, and there are some questions, which we address, regarding the quality of the data.

In addition to the determinants of transport costs, we want to know the extent to which transport costs choke off trade. To do this we undertake a gravity modelling exercise, incorporating the same geographical and infrastructure measures that we use in estimating trade costs. This analysis strongly confirms the importance of these variables in determining trade, and also enables us to compute estimates of the elasticity of trade flows with respect to transport costs. We find that this elasticity is large, with a 10 percentage point increase in transport costs typically reducing trade volumes by approximately 20%.

Taken together, our approaches provide a rather consistent picture of the determinants of transport costs, and in particular of the importance of infrastructure in source and destination countries, and in any transit countries used by landlocked economies. We draw out the implications of our findings by looking in some detail at trade and transport costs in Sub-Saharan Africa. Our measures indicate that many of these economies have extremely high transport costs, and we show how taking infrastructure into account explains part of the relative trade performance of these countries.

The paper is organized as follows. In the next section we discuss the determinants of transport costs and present estimates for the transport cost equation using the shipping data and the cif/fob data. In section three we present the gravity results. In section four we compare and contrast the results from the transport cost and gravity analyses, and derive an estimate of the elasticity of trade flows with respect to transport costs. We show that improvements in the infrastructure of landlocked countries and their transit countries can dramatically increase trade flows; moving from the 75th percentile to the 25th in the distribution of infrastructure quality more than halves the cost penalty for being landlocked, and more than doubles the volume of trade. In section five we analyze trade and transport costs in Sub-Saharan Africa, finding that infrastructure accounts for much of Africa's poor performance. Section 6 concludes, and presents some tables that summarise our main quantitative findings.

2. Transport costs

2.1 The determinants of transport costs

Let T_{ij} denote the unit cost of shipping a particular good from country *i* to country *j*. We suppose that it is determined by:

$$T_{ij} = T(x_{ij}, X_i, X_j, \mu_{ij}) \tag{1}$$

where x_{ij} is a vector of characteristics relating to the journey between *i* and *j*, X_i is a vector of characteristics of country i, X_j is a vector of characteristics of country j, and μ_{ij} represents all unobservable variables.

What are the relevant observable characteristics of countries and the journeys between them? For the journey between we use two types of measures, both standard in the literature. The first is whether the countries share a common border, and the second is the shortest direct distance between countries. The importance of distance for transport costs is obvious but why should sharing a border reduce transport costs after controlling for distance? First, neighboring countries typically have more integrated transport networks which reduce the number of transhipments, e.g. from rail to road or across different types of rail gauge. Second, neighboring countries are more likely to have transit and customs agreements that reduce transit times and translate into lower shipping and insurance costs. Finally, the higher volume of trade between neighbor countries dramatically increases the possibilities for backhauling allowing the fixed costs to be shared over two trips.

For country characteristics, we focus on geographical and infrastructure measures. The main geographical measures are simply whether the country is landlocked and whether it is an island. The infrastructure measure we use is designed to measure the costs of travel in and through a country. It is constructed as an average of the density of the road network, the paved road network, the rail network, and the number of telephone main lines per person. In our regressions we always work with an inverse measure of this index, so that an *increase* in the variable *inf* is expected to be associated with an *increase* in the costs of transport. Details on the construction of this and other variables are given in the appendix.

2.2 Shipping from Baltimore:

Our first results are based on the costs of shipping a standard 40' container from Baltimore in the U.S. to different destinations around the world. The data was provided by a firm that handles forwarding for the World Bank, and covers 64 destination cities, 35 of which are in landlocked countries (a list of these and summary statistics are given in tables AII and AIV of the appendix). This source of data has two major advantages. One is that journeys can be broken down into component parts – the data gives the landfall city for each journey, as well as the final destination city -- allowing the estimation of the effect of land and sea distance separately. The other is that the good shipped is homogeneous, avoiding compositional problems that can occur in aggregate data.[6]

We estimate a linear version of equation *(1)* both for the entire journey (columns 1 and 3 of table 1) and for the journey divided into the sea journey (to the port) and the land journey (from the port, columns 2 and 4). More specifically we estimate:

$$T_{ij} = \alpha + \beta' x_{ij} + \gamma' X_i + \delta' X_j + \nu_{ij} \qquad (2)$$

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[6] UNCTAD (1995, pg. 58) presents similar data for a sample of four coastal countries and nine landlocked countries in Sub-Saharan Africa. Livingstone (1986) uses quotes made by regular shippers to the Crown agents from the UK to eight African countries. The small size of the sample in both studies does not allow for a systematic examination of the determinants of transport costs.

where *i* corresponds to Baltimore and *j* represents the destination city. The error term ν_{ij} is assumed to be independent of the explanatory variables and normally distributed.

It is not clear a priori what the most appropriate functional form is. On the one hand the fact that we are adding up over the different legs of the trip, i.e. the cost of going through the infrastructure of importer, exporter and the cost of shipping between them, suggests a linear form. On the other hand, it is possible that there are interactions between the cost variables that would make a nonlinear form more suitable. The simplest example is that an increase in land distance should increase the cost of going through a given infrastructure. For this reason we also experimented with some nonlinear forms, but they were rejected by the data.[7] Therefore table 1 presents the OLS estimation results of the linear form given by equation (*2*).

The first two columns give results excluding the infrastructure variables. There are three main conclusions. First, being landlocked raises costs by $3,450 – compared to a mean cost for non-landlocked countries of $4,620. Second, breaking the journey into an overland and sea component (column 2) considerably improves the fit of the equation, and gives a much larger coefficient for the overland portion of the trip when compared to sea distance; an extra 1000 km by sea adds $190 whereas a similar increase in land distance adds $1,380. When this value is compared to the $380 per 1000km predicted by total straight line distance (column 1) it becomes clear that using the latter measure leads to a large underestimate of the impact of overland distance on transport costs. Third, the additional transport cost from being landlocked is not fully explained by the extra overland distance that must be overcome to reach the sea. Although the final city destination for landlocked countries is on average four times further from the sea than the final city destination of coastal countries in this sample the landlocked dummy remains significant after land distance is controlled for. There are several possible reasons for this, arising from border delays or transport coordination problems, uncertainty and delays creating higher insurance costs, and direct charges that may be made by the transit country[8].

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[7] This is true even when quadratic distance terms are added to capture any non-linearity. These terms are insignificant, further justifying the use of the linear land and sea distance measures. We also estimated (2) including the per capita income of the destination country, on the grounds that low income countries might have high transport costs for a variety of reasons other than infrastructure. It was not significant

Table 1: Cost of shipping 40' container from Baltimore

Dependent variable: Transport cost (T_{ij}) (Thousand US $, 1998)

	1	**2**	**3**	**4**
Inf			1.31^{**}	1.56^{***}
			(2.51)	(2.92)
Inftran			1.34^{**}	0.67
			(1.93)	(0.88)
ldldummy	3.45^{***}	2.17^{***}		
	(4.75)	(2.94)		
Distance	0.38^{**}		0.29^{*}	
	(2.6)		(1.84)	
Distsea		0.19^{**}		0.18^{*}
		(2.12)		(1.74)
Distland		1.38^{***}		1.49^{*}
		(4.66)		(1.77)
Constant	1.1	2.06^{*}	0.11	-0.1
	(0.95)	(1.85)	(.093)	(-0.07)
N	64	64	47	47
R sq.	0.32	0.47	0.38	0.43
F-test (p-values)				
Inf, Inftran	-	-	-	0.00
Inftran, distland	-	-	-	0.03

Notes:

1) Distances are in 1000's km. The infrastructure and income variables are an average between 1990 and 1995 (the latest year available). The sample used in the last two specifications is reduced to the countries for which the infrastructure variables are also available. ldldummy=1 if the country has no access to the sea, 0 otherwise.

2)***,**,* indicates significance at the 1%, 5% and 10% level respectively. T-statistics in parenthesis. The F-tests are for the pairs of variables indicated, the p-values show the level at which the null of no joint significance is rejected.

3) For specifications 1 and 3 the standard errors were adjusted to correct for heteroskedasticity.

Columns 3 and 4 introduce our measures of the inverse infrastructure of the destination (*inf*) and, for landlocked countries, the transit country (*inftran*) for the smaller sample which this

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[8] For example, Kenya charges a transit goods license for road transit of $200 (per entry or 30 days) and tolls on trucks, UNCTAD (1997, pg. 11).

data covers.[9] The signs of these are as expected, inferior infrastructures leading to higher transport costs. We can also ask what proportion of the predicted value is explained infrastructures vs. distance. For coastal economies own infrastructure explains 40% of the predicted cost, for landlocked countries own infrastructure explains 36% and transit infrastructure 24% of the cost.

The final specification (column 4) breaks distance into the overland and sea components. The coefficients on these distance variables are very similar to those in the full sample (column 2). Splitting the distance variable makes the coefficient for transit infrastructure smaller and insignificant because of the variable's high positive correlation with land distance. Moreover transit and own infrastructure are also highly correlated. This multicollinearity poses problems for identifying the separate effects of the two variables, but the tests of significance at the bottom of table 1 confirm the importance of the transit variable when considered jointly with *either* own infrastructure *or* land distance. To re-emphasize the relative importance of infrastructure, an improvement of Inf from the 75th percentile to the median is equivalent to a distance reduction of 3,466 sea km, or 419 land km.[10].

2.3 Cif/fob measures

Our second set of experiments is based on the cif/fob ratio as derived from the IMF Direction of Trade Statistics. Importing countries report the value of imports from partner countries, inclusive of carriage, insurance and freight (cif), and exporting countries report their value free on board value (fob), which measures the cost of the imports and all charges incurred in placing the merchandise aboard a carrier in the exporting port. Denoting the fob price of goods shipped from i to j by p_{ij} we define t_{ij}, the ad valorem transport cost factor as,

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[9] The landlocked dummy is not included because of its multicollinearity with transit infrastructure.

[10] For 20 landlocked countries in the sample we have both the costs of shipping to the port, and the full cost of shipping to the landlocked destination (eg, the cost of shipping from Baltimore to Durban and that from Baltimore to Harare via Durban). This enables us to look at the determinants of the incremental costs associated with the final stage of the journey. Final destination infrastructure is significant and positive, although neither incremental distance nor port infrastructure are. This is due both to the small number of observations and to details that become apparent upon inspection of the data. For example, shipping from Baltimore to Durban costs $2,500: shipping the 1,600 Kms further to Lusaka costs an additional $2,500, whereas the 347 Kms from Durban to Maseru (Lesotho) costs an additional $7,500. This points to the importance of fine details of geography, market structure and trade volumes, in addition to the broader picture painted by the econometrics.

$$t_{ij} \equiv cif_{ij} \;/\; fob_{ij} = (p_{ij} + T_{ij})/p_{ij} = t(x_{ij}, X_i, X_j, \tilde{\mu}_{ij}) \qquad (3)$$

where the final equation uses the determinants of T_{ij} given in (1).

The ratio cif/fob provides the measure of transport costs on trade between each pair of countries. In theory the fob and cif prices are border prices and thus it would seem that own and trading partner infrastructures as defined here should not affect these rates. There are three reasons why they are indeed relevant. First road, rail and telephone infrastructure are likely to be highly correlated with port infrastructure (for which we have no data) and the latter would be important even if the prices were pure border prices. Second, the insurance component will reflect the total time in transit, i.e. from door to door, not just border to border; total transit time is likely to be a function of own and partner infrastructure. Finally, according to U.N. experts on customs data, the fob and cif figures rarely measure actual border prices, instead measuring the prices at the initial point of departure and final destination respectively[11]. Thus own and partner infrastructure should be included in the estimation.

Assuming that t can be approximated by a log linear function up to some measurement error, we can write the observed transport cost factors t_{ij} :

$$\ln t_{ij} = \tilde{\alpha} + \tilde{\beta}' x_{ij} + \tilde{\gamma}' \ln X_i + \tilde{\delta}' \ln X_j + \omega_j \qquad (4)$$

where the tildes distinguish this set of parameters from those of equation (2). The final term, ω_j, contains unobserved variables, which we assume are uncorrelated with the explanatory variables, and random measurement error. As in the previous section, functional form is to a large degree an empirical question. We have previously noted that there are good reasons why T may be non-linear in its determinants, for example if country j does not have a container port then country i will not benefit from its own container facilities in exporting to j.[12] We found that the log linear form fitted the cif/fob data considerably better than the linear one.

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[11] E-mail contact with Mr. Peter Lee at the U.N.

[12] Even if the true transport cost function, T^* is linear there is no reason for the reduced form of the transport cost *rate,* t^* to have the same functional form. The reason for this is that for small exporters (facing a perfectly elastic demand) the fob price, p_i , will itself depend on the average transport cost between themselves and their importers an effect captured by the reduced form of t^*_{ij} .

Several questions have been raised about the use of this cif/ fob transport cost data.[13] The first is that the measure aggregates over all commodities imported, so is biased if trade on high transport cost routes systematically involves lower transport cost goods. This suggests that our estimates in fact will underestimate the true magnitude of transport costs.[14] The second is the presence of measurement error, arising particularly from the fact that exports are not always very accurately reported. To the extent that this measurement error is uncorrelated with the explanatory variables this should not be a problem. Further data problems we deal with in the following way. (i) Approximately 25% of potential bilateral trade flows are dropped because of missing data from one of the partner countries. (ii) Some countries had cif import values lower than the corresponding fob export value which would imply negative costs; we drop all such observations. (iii) The IMF sometimes imputes a cif/fob ratio of 1.10: these were also dropped. More details on sample selection can be found in the notes to table A1 in the appendix. In section 4 below, we compare the results obtained using the cif/fob data with those from the shipping cost data, and the comparison indicates that the cif/fob data contains information about the cross sectional variation in transport costs that is consistent with the shipping cost data.

The model is estimated with 1990 data for a sample of 103 countries. Deleting observations that are missing, estimated, or give negative transport costs leaves 4615 observations. Approximately 22% of all country pairs in our sample are reported to have no trade. One important reason for this is that at high enough transport costs two countries will not find it profitable to trade. This implies that for these countries the transport cost measure is censored at some upper limit and this motivates our use of an upper limit Tobit. We assume that for those countries that report zero trade the transport cost of trading takes the value of the upper limit in the sample.

Estimation results

The results from the estimation of (*4*) are given in table 2. The first two rows of the table are characteristics of the journey between i and j; the log of distance, (ln*distance*), and whether i and j share a common border (*border*). The remainder are characteristics of the importer country

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[13] See Hummels (1998a) for a good discussion of these issues.

[14] Hummels 1998b provides a good account of the cross-commodity variation in transport costs using disaggregated data for four countries.

and its trading partner; a dummy for an island (*isldummy* and p*isldummy*); the per capita income of the importing and exporting countries, (ln*Y/cap* and *ln*p*Y/cap*). Finally, the infrastructure measures (ln*inf* and *ln*p*inf*) and the infrastructure of transit countries (ln(1+ *inftran*) and ln(1+ p*inftran*)).

The first column of the table gives the effect of distance alone, and the second column gives a specification with journey and country characteristics, apart from infrastructure. We see that distance and border effects are as expected. Being or trading with an island reduces transport costs (although these effects are barely significant), and high per capita income reduces transport costs. The infrastructure variables are included in column 3, and all are significant with the expected sign. The final column gives results when partner country variables are replaced by dummies for each partner country. As expected, this increases the explanatory power of the equation. The own infrastructure effects continue to be highly significant.

Several important messages come from these results. The first is the quantitative importance of the infrastructure effects. If a country could improve its infrastructure from the median to the top 25th percentile, then its cif/fob factor would fall from 1.28 to 1.11, this being equivalent to becoming 2358km closer to all its trading partners.[15] Conversely, an infrastructure deterioration from the median to the 75th percentile raises the predicted cif/fob factor from 1.28 to 1.40, equivalent to becoming 2016km further away from all trading partners.

We can ask a similar question for the border effect. How much closer must two otherwise identical countries be if they do not share a border and are to have the same transport costs? The answer is that they would need to be 932km closer – compared to a mean distance between capitals of bordering countries of 1000 km.[16] Thus, the positive border effect on trade - which is typically found in gravity model estimates - is very important for transport cost reasons other than distance, suggesting that transhipment costs and the integration of transport networks is quite important. We turn to the cost of being landlocked in more detail in section 4.1.

Finally, it is worth comparing our estimates with those using the simple and most commonly used proxy for transport costs, distance. As shown by the Pseudo-Rsq, using distance alone explains only 10% of the variation of transport costs (column 1) compared to almost 50%

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[15] Uses estimates from column 4, and evaluated at median cif/fob ratio of 1.28 and median distance of 7555 respectively, so 1.11=1.28*(0.95/1.41)^(0.36) and 2358=7555-7555**(0.95/1.41)^(0.36/0.38)

[16] Evaluated at the mean distance for bordering countries, of 1000km, as new distance = 1000*exp(-1.02/.38).

when the remaining geography and infrastructure measures are added (column 3). Clearly distance fails to explain a significant part of the variation in transport costs.

Table 2. Bilateral transport cost factor (1990)

Dependent variable: ln Transport cost factor cif/fob, (ln t_{ij});

	1	2	3	4
ln*Distance*	0.25***	0.23***	0.21***	0.38***
	(6.74)	(6.02)	(5.65)	(10.17)
border		-1.35***	-1.36***	-1.02***
		(-7.77)	(-7.78)	(-6.30)
isldummy		-0.12***	-0.09	-0.06
		(-1.73)	(-1.23)	(-0.94)
pisldummy		-0.16**	-0.12*	
		(-2.18)	(-1.65)	
ln*Y/cap*		-0.31***	-0.23***	-0.24***
		(-19.97)	(-9.64)	(-10.78)
lnp*Y/cap*		-0.45***	-0.30***	
		(-27.94)	(-12.84)	
ln*Inf*			0.34***	0.36***
			(3.92)	(4.47)
lnp*Inf*			0.66***	
			(7.64)	
ln(1+*Inftran)*			0.21**	0.36***
			(2.15)	(4.07)
ln(1+p*Inftran)*			0.24***	
			(2.51)	
				Partner fixed effects
Pseudo Rsq.	0.10	0.46	0.48	0.60
σ	1.92	1.70	1.69	1.53

Notes:

1) N=4516; Tobit estimates. Pseudo Rsq given by the correlation of actual and predicted ln t_{ij}; constants included but not reported; exporter fixed effects included in 4 but not reported; σ is the standard error of the Tobit estimate.

2) T-statistics in parenthesis**:** ***,**,* indicates significance at the 1%, 5% and 10% level respectively.

3) The original transit variables, *Inftran*, ranges from 0 for the coastal economies to approximately 1.7. Before taking the log we add 1 to the measure to correctly reflect that coastal economies bear no extra infrastructure transport cost. To compare the own and transit elasticities we need to multiply the coefficient of ln*Inftran* (reported above) by *Inftran /(1+ inftran).* This ratio ranges from 0.40 to 0.63 for landlocked countries in this sample.

4) The Tobit coefficients correspond to the marginal effects for the full sample, including the zeros.

3. Trade volumes:

Instead of looking directly at trade costs, we now look at the trade flows they support, by estimating a gravity model including the infrastructure variables used above. There are two main reasons for doing this. First, the variables identified as being important in transport cost equations should also be important in the trade equations, and we want to check that this is so. Second, by using the same variables in estimating transport costs and trade equations we are able to compute estimates of elasticities of trade flows with respect to transport costs.

The gravity equation is the standard analytical framework for the prediction of bilateral trade flows. Its empirical use in the context of international trade dates back to the early 1960's, and theoretical underpinnings were developed later[17]. Despite the abundant number of theoretical derivations of the gravity equation, the majority of the authors do not model transport costs explicitly, exceptions being Bergstrand (1985) and Deardorff (1998). More recently, Bougheas et. al (1999) incorporate transport infrastructure in a two country Ricardian model and show the circumstances under which it affects trade volumes[18].

Bilateral imports, M_{ij}, depend on GDP, Y_j, and Y_i, in the standard way, and on the transport cost factor, t_{ij}, which we model in terms of the geographical and the infrastructure measures used in the preceding analysis. So we have:

$$
\begin{gathered}
M_{ij} = \varphi Y_j^{\phi_1} Y_i^{\phi_2} t_{ij}^{\tau} \varepsilon_{ij} \quad \textit{or} \\
\ln M_{ij} = \phi_0 + \phi_1 \ln Y_j + \phi_2 \ln Y_i + \tau [\tilde{\beta}' \ln x_{ij} + \tilde{\gamma}' \ln X_i + \tilde{\delta}' \ln X_j] + \eta_{ij}
\end{gathered}
\tag{5}
$$

where the second equation is obtained by taking logs and substituting out the true transport cost rate as given by equation (4) in the cif/fob section. We estimate this equation in the form:

$$
\begin{aligned}
\ln M_{ij} = {} & \phi_0 + \phi_1 \ln Y_j + \phi_2 \ln Y_i + \phi_3 \ln Distance_{ij} + \phi_4 border_{ij} + \phi_5 isldummy_j + \phi_6 isldummy_i + \phi_7 \ln Inf_j \\
& + \phi_8 \ln Inf_i + \phi_9 \ln(1 + Inftran_j) + \phi_{10} \ln(1 + Inftran_i) + \phi_{11} \ln(Y / cap_j) + \phi_{12} \ln(Y / cap_i) + \eta_{ij}
\end{aligned}
\tag{5'}
$$

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[17] See Frankel (1997) for a discussion of earlier references. For different theoretical underpinnings see Anderson (1979), Bergstrand (1985 and 1989).

[18] Bougheas et al (1999) estimate augmented gravity equations for a sample limited to nine European countries. They include the product of partner's km of motorway in one specification and that of public capital stock in another and find that these have a positive partial correlation with bilateral exports.

where M_{ij} represents country j's imports from i valued at cif, Y_i is GDP and the remaining variables are those introduced in the shipping and cif/fob sections.[19] The model is estimated by Tobit using the same data set as used for transport costs. 22% of all observations in the sample used are reported as zeros, in which case the import values are set equal to the censoring point, which is the minimum value in the sample.

Estimation results

Table 3 contains the results of the estimation. Income, distance, border and island effects have the expected signs, as usual in gravity estimates. The striking result is the strong performance of the infrastructure variables used in the preceding analysis. First, all infrastructure variables (importer, exporter and transit if either country is landlocked) have the correct sign and are significant at the 1% level. Moreover, they have sizeable effects on trade volumes. Moving from the median to the top 25th percentile in the distribution of infrastructure raises trade volumes by 68%, equivalent to being 2005km closer to other countries.[20] Moving from the median to the bottom 75th percentile reduces trade volumes by 28%, equivalent to being 1627km further away from trading partners.

We now turn to detailed comparison of the results from the transport cost equation, the cif/fob equation, and the gravity estimates.

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[19] The transit infrastructure variables are adjusted for neighboring countries, so if i and j are neighbors and j (i) is landlocked then $Inftran_j$ ($Inftran_i$) is set to zero since no transit country must be used. So, to be more precise, in *(5')* we should write for j $Inftran_j*(1-border_{ij})$ not $Inftran_j$ and similarly for i.

[20] Uses estimates from column 4, and evaluated at median distance of 7555, so 1.68=(0.95/1.41)^(-1.32) and 2005=7555-7555**(0.95/1.41)^(1.32/1.69)

Table 3. Gravity: Value of imports into country j from country i.

Dependent variable: ln M_{ij};

	1	2	3	4
ln*Y*	1.28***	1.05***	0.99***	1.03***
	(53.51)	(30.3)	(28.04)	(31.30)
lnp*Y*	1.55***	1.35***	1.28***	
	(60.57)	(37.48)	(34.67)	
Ln*Distance*	-1.65***	-1.43***	-1.37***	-1.69***
	(-24.07)	(-18.7)	(-18.03)	(-22.40)
border		2.45***	2.52***	1.85***
		(7.03)	(7.25)	(5.67)
isldummy		0.48***	0.35**	0.41***
		(3.23)	(2.46)	(3.06)
pisldummy		0.48***	0.4***	
		(3.34)	(2.78)	
ln*Y/cap*		0.41***	0.16***	0.12**
		(8.78)	(2.96)	(2.28)
lnp*Y/cap*		0.34***	0.16***	
		(7.29)	(3.04)	
ln*Inf*			-1.32***	-1.32***
			(-7.49)	(-8.07)
lnp*Inf*			-1.11***	
			(-6.26)	
ln(1+*Inftran)*			-0.6***	-0.77***
			(-3.04)	(-4.18)
ln(1+p*Inftran)*			-0.45**	
			(-2.26)	
				Partner fixed effects
Pseudo Rsq	0.79	0.8	0.8	0.83
σ	3.47	3.39	3.34	3.08

Notes:

1) N=4516; Tobit estimates. Pseudo Rsq given by the correlation of actual and predicted ln M_{ij}; constants included but not reported; σ is the standard error of the Tobit estimate. All variables and sample selection as in table 2.

2) T-statistics in parenthesis ; ***, **,* indicates significance at 1%, 5% and 10% level respectively**.** Constant included in all specifications but not reported.

4. Comparison and quantification

In this section we compare the results of our three approaches, and do so in a way that facilitates the assessment of the quantitative importance of infrastructure and geographical location for transport costs and for trade.

4.1 The cost of being landlocked

Table 4 shows the disadvantage of being landlocked, relative to being an average coastal country, for different values of the own and transit country infrastructure. The first part of the table, based on the shipping data, indicates that the median landlocked country has transport costs 55% higher than the median coastal economy. However, improving own infrastructure to the level of the best 25th percentile amongst landlocked countries cuts this cost penalty to 41%; improvement by the transit country cuts the penalty to 48%, and if both improvements are made, the penalty drops to 33%. The second part of the table is based on the cif/fob measure, and reports ratios of (cif/fob-1) for landlocked countries relative to the median coastal economy. This gives slightly smaller cost penalties, with the median landlocked economy's transport costs 46% higher than the median coastal economy's. Improving own and transit country infrastructure to the 25th percentile reduces this penalty to 34% and 43% respectively, and if both are improved the penalty drops to 31%.

Comparison of these results assures us that the estimates from our different data sources are consistent, and that the cross-sectional variation in the cif/fob measure does contain useful information regarding transport costs. Although the cif/fob data predicts relative costs that are 9 percentage points lower than the shipping data at the median infrastructure values, the partial effects of the own and transit infrastructure variables are similar across the data sets as illustrated in figure AI in the appendix. The similarity between the predicted effects on relative transport costs is particularly striking in the case of own infrastructure.

Table 4: The cost of being landlocked.

Transport costs of landlocked economies relative to representative coastal economy: Shipping data

		Own Infrastructure Percentiles		
		25th	Median	75th
Transit Infrastructure Percentiles	25th	1.33	1.48	1.67
	Median	1.41	1.55	1.74
	75th	1.51	1.65	1.84

Transport costs of landlocked economies relative to representative coastal economy: cif/fob data, ratios reported for (cif/fob – 1).

		Own Infrastructure Percentiles		
		25th	Median	75th
Transit Infrastructure Percentiles	25th	1.31	1.43	1.65
	Median	1.34	1.46	1.69
	75th	1.37	1.49	1.72

Trade volume of landlocked economies relative to representative coastal economy:

		Own Infrastructure percentiles		
		25th	Median	75th
Transit Infrastructure Percentiles	25th	0.55	0.42	0.26
	Median	0.53	0.40	0.25
	75th	0.50	0.38	0.24

Notes:

1) The construction of the variables for the first two blocks of the table is as follows: we calculate the predicted transport cost over the landlocked countries allowing *inf* and *inftran* to vary as well as the landlocked dummy but keeping all other variables at the level of the representative coastal country (median value over non-islands). This is then divided by the predicted transport cost (or rate for the cif/fob) over the representative coastal country. For the last block a similar procedure is used. The percentiles are taken over the landlocked countries sample.

2) The specifications used are column 3 table 1, column 3 of table 2 and column 3 in table 3.

The final part of table 4 undertakes an analogous experiment for trade volumes, asking how the volume of trade of representative landlocked economies compares with the average coastal economy given the same incomes, i.e. varying only the transport cost variables. The difference is dramatic, with the median landlocked economy having only 40% the trade volume. Improvements in own infrastructure from the median to the 25th percentile increasing the volume of trade by 13 percentage points, improvement in transit country infrastructure increasing the volume by 2 percentage points, and a simultaneous improvement leading to an increase of 15 percentage points in the volume of trade.

4.2 The elasticity of trade with respect to transport costs.

It is natural to link our estimates of trade volumes and of transport costs, by computing the elasticity of trade volumes with respect to the transport cost factor as given by the parameter τ in equation (5). In this sub-section we offer two approaches to doing this, one based on comparison of the estimates of the cif/fob and gravity models, and the other based on regression of trade volumes on predicted trade costs.

The estimates from the cif/fob and gravity models (equations (*4*) and (*5*)) provide over-identifying restrictions for τ, one for each of the determinants in the transport cost equations. We focus on the estimates of distance, border, and own and transit country infrastructure,[21] and the elasticities previously found in the gravity estimation ($\hat{\phi}$) and the cif/fob estimation ($\hat{\tilde{\delta}}$) are reproduced in the first two columns of table 5. The remaining columns give the predicted elasticity of trade with respect to the transport cost factor, $\hat{\tau}$, obtained as the ratio of the gravity and cif/fob elasticities.

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[21] Of the other two variables, it is likely that income per capita may enter the gravity equation for reasons other than transport costs, and the island dummy is not significant.

Table 5
Estimates of Import Elasticity w.r.t. the transport cost factor

	Elasticity estimates		
	Gravity	Cif/fob	Trade
Variable	$\hat{\phi}$ [1]	$\hat{\tilde{\delta}}$ [2]	$\hat{\tau} = \hat{\phi} / \hat{\tilde{\delta}}$
Distance	-1.37	0.21	-6.47
lnInf	-1.32	0.34	-3.86
ln(1+inftran)	-0.60	0.21	-2.87
Border	2.52	-1.36	-1.85
Pinf	-1.11	0.66	-1.67
ln(1+Pinftran)	-0.45	0.24	-1.84

Notes:

1) cif/fob elasticities correspond to the estimates of column 3 in table 2.
2) Gravity elasticities correspond to the estimates of column 3 in table 3.
3) We also calculate upper and lower bounds for the trade elasticities using the 95% confidence intervals for the gravity and cif/fob coefficients these are respectively for: Distance (-4.28,-10.98); *lnInf* (-1.90,-9.75); *ln(1+inftran)* (-0.53,-53.65); *Border* (-1.08,-3.15); *Pinf* (-0.91,-2.94) and *ln(1+Pinftran)* (-0.14,-15.64).

The point estimates of τ vary quite widely, from –6.47 on the distance variable, to less than –2 for partner infrastructure measures and border. The likely reason for this is that some of the variables influence trade volumes through channels other than measured transport costs. For example, distance and border effects might be expected to influence trade volumes through channels such as information flows and language and cultural ties, which would not show up in measured transport costs.[22]

Our second approach is to use predicted values of transport costs (from equation (4)) as independent variables in the gravity model (equation (5)). In estimating this we exclude variables which, a priori, we think only affect trade volumes through transport costs (the infrastructure measures), leaving in those that might affect trade volumes directly. Thus, Table 6 reports regressions of trade volumes on predicted values of the transport cost factor, incomes, per capita incomes, and also distance and border effects. The first column takes as dependent

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[22] Geraci and Prewo (1977) estimate τ for a sample of 18 OECD countries. They find a higher elasticity ($\tau = -10$) than the one we find. This is possibly because of the restriction of their sample to high income countries. More importantly perhaps is the fact that they do not estimate an upper limit tobit for the transport cost. This is likely to lead to an under estimate of the predicted transport cost factor and a consequent upwards bias of the transport cost elasticity

variable predictions of the transport cost factors from column 3 of table 2, while the second column has partner fixed effects, so uses predictions from column 4 of table 2.

Table 6: Trade volumes and predicted transport costs

Dependent variable: ln M_{ij}

	1	2
$\ln(\hat{t}_{ij})$	-2.24 (-10.80)	-3.11 (-10.01)
$\ln Y$	1.01 (29.42)	1.03 (31.28)
$\ln pY$	1.26 (34.76)	
$\ln Y/cap$	-0.25 (-3.23)	-0.59 (-5.58)
$\ln pY/cap$	-.57 (-5.93)	
$\ln Distance$	-0.87 (-9.99)	-0.51 (-3.74)
border	-0.50 (-1.14)	-1.39 (-3.02)
		Partner fixed effects
Pseudo Rsq.	0.8	0.83
σ	3.35	3.08

Notes: The s.e. of $\ln(\hat{t}_{ij})$ were not adjusted for the fact that it is a predicted variable, and therefore underestimate the true estimate error.

The coefficient on the predicted transport cost factor, $\hat{t}_{ij}$, measures the elasticity of trade volume with respect to the transport cost factor, τ, and, in column 1, this takes value –2.24.[23] Distance remains highly significant, although the coefficient falls markedly compared to the gravity estimates of table 3. This suggests that distance effects trade volumes both through transport costs and independently through other channels, such as information, which could account for the large value of $\hat{\tau}$ associated with the distance coefficients in table 5. Of the other variables, the border coefficient is insignificant, while incomes per capita enter with negative sign, suggesting that once transport costs are controlled for, low per capita income countries

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[23] Since this is the transport cost factor, an increase from, say, 1.1 to 1.2 is a 9% increase not a doubling.

trade rather more than high per capita income countries. Column 2 reports analogous results when partner country fixed effects are included. The main difference is that this increases the absolute value of the estimated elasticity τ to –3.11, while reducing further the independent role of distance.

Taking tables 5 and 6 together enables us to make an informed judgement about the quantitative importance of transport costs in determining trade flows. Results suggest an elasticity of trade flows with respect to the transport cost factor in the range –2 to –3.5. Taking a value of –3 means that doubling transport costs from their median value (i.e. raising the transport cost factor from 1.28 to 1.56) reduces trade volumes by 45%. Moving from the median value of transport costs to the 75th percentile (transport cost factor 1.83) cuts trade volumes by two-thirds.

5. Transport costs, infrastructure and Sub-Saharan African trade

Our results show how damaging poor infrastructure and landlockedness are to trade. We now extend the quantitative implications of our findings by applying them to Sub-Saharan African (SSA) trade and addressing the question, is African trade 'too low'? The answer is that low trade levels are largely explained by infrastructure and geography.[24,25]

5.3 Is SSA trade 'too low'?

There is a common belief that Africa trades 'too little' both with itself and with the rest of the World. Frankel (1998) reports intra-regional trade shares in 1990 of 4% for the whole of Africa compared to 44% for East Asia, and Amjadi et al. (1996) discuss the marginalization of SSA in World trade. The poor performance is typically attributed to protectionist trade policies (Collier (1995), Collier and Gunning (1999)) and high transport costs due to poor infrastructure and inappropriate transport policies (Amjadi and Yeats (1995)).

This view has been contested by Foroutan and Pritchet (1993), who show that the low level of intra-African trade is explained by the usual determinants of a gravity equation.

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[24] Evidence for the importance of transport costs for Africa's export performance is given by Amjadi and Yeats (1995) and Amjadi, Reincke and Yeats (1996). In the former study it is reported that, according to balance of payments statitics, SSA's net insurance and freight paymentsamounted to 15% of their exports' value. By comparison for all developing countries the payments averaged 5.8%.

[25] Collier and Gunning (1999, p. 71) provide a brief description of the quantity and quality of infrastructure in SSA.

Similarly, Coe and Hoffmaister (1998) conclude that bilateral trade between SSA countries and industrial countries in the 1990´s was not unusually low. Finally, Rodrik (1998) finds that the trade/gdp ratios of SSA countries are comparable to those of countries of similar size and income and that Africa's marginalization is mainly due to low income growth.

What evidence does our data provide on this, and to what extent can it be accounted for by the infrastructure variables we have identified as being so important? To answer this we re-estimated the baseline and infrastructure specifications of our transport cost and gravity models, augmenting them with African dummies: African importer (*Africa*), African exporter (p*Africa*), African importer and exporter (*AA*), and an interaction of the latter with distance (*AAdistance*). Table 7 provides the estimates, with columns 1-4 reporting the transport cost equation, and 5-8 the gravity equation.

Starting with the columns 1 and 5, we see that intra SSA trade costs are substantially higher and trade volumes substantially lower than those for non-SSA countries. The row labelled *'Africa factor'* gives the combined effects of the Africa dummies, so we see that intra-SSA transport costs are 136% higher (2.36=exp(0.08+0.52+0.26)) and trade volumes 6% lower (0.94=exp(-0.23-0.59+0.76)). Thus the basic specification cannot account for the poor performance of African trade even when though it controls for both geographical variables (border and island dummies) and per capita income.

Columns 3 and 7 add the infrastructure measures. The key finding here is that infrastructure accounts for nearly half the transport cost penalty borne by intra-SSA trade, the penalty attributable to the Africa dummies dropping from 136% to 77%. The Africa penalty on trade flows is actually overturned, the estimates suggesting that, once we control for infrastructure (column 5) intra-SSA trade is 105% *higher* than would be expected.

It is sometimes claimed that poor communications infrastructure in Africa entails higher transport costs per kilometre within SSA than elsewhere. We investigate this with the variable *AAdistance*, which is zero for trade involving one non-African country, and equal to distance for trade between a pair of African countries. Foroutan and Pritchet (1993) use a similar variable and find that it is insignificant which leads them to conclude that:

> *"The gravity model gives little evidence that in fact distance is a greater barrier to intra-SSA trade than it is for other countries. This result goes against the apparently common*

> *feeling that the poor quantity and quality of communications and transport infrastructures between SSA countries is a major obstacle to intra-SSA trade"*

We find the opposite, with columns 2 and 4 indicating that the variable is significant in raising transport costs, and columns 6 and 8 indicating that it is significant in reducing trade volumes.[26] Thus, controlling for infrastructure (column 4), African transport costs are 8% lower on journeys of 1000km, but 121% higher on journeys of 3000km. One way to summarize the results including *AAdistance,* is to calculate the critical distance above which an African pair faces a penalty compared to a non-African pair. Looking at transport costs, (columns 2 and 4), the distance is 826km, rising to 1110km once we control for infrastructure. Looking at trade volumes (columns 6 and 8), the distance is 2196km, rising to 4684km once infrastructure is included. It is interesting to note that including the infrastructure measures more than doubles the critical distance for trade, and that the majority of country pairs in SSA on opposite coasts exceed that critical distance.

Pulling our Africa results together, there are several main conclusions. First, intra-African transport costs are higher and trade volumes lower than would be predicted by a simple model (Table 7 columns 1 and 5). However, much of this can be attributed to poor infrastructure, and to the particularly high cost of distance in Africa. Our results confirm the fact that intra-African trade is concentrated at the sub-regional level with less East-West trade than would be expected between a pair of otherwise similar countries in the rest of the world.

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[26] The finding in Foroutan and Pritchet (1993) is most likely due to the fact that *AA* and *AAdistance* are multicollinear and thus they are not able to identify either. In our sample the correlation between these variables is over 0.9.

Table 7: Africa: Transport costs and gravity.

Dependent variable:	Transport costs: (ln t_{ij})				Imports: (ln M_{ij})			.
	1	2	3	4	5	6	7	8
ln*Y*					1.05***	1.05***	1.02***	1.02***
					(27.44)	(27.45)	(26.96)	(26.99)
lnp*Y*					1.31***	1.31***	1.28***	1.28***
					(33.47)	(33.45)	(32.69)	(32.70)
Ln*Distance*	0.29***	0.23***	0.26***	0.20***	-1.39***	-1.31***	-1.29***	-1.21***
	(7.38)	(5.67)	(6.57)	(4.88)	(-17.45)	(-16.06)	(-16.29)	(-14.93)
border	-1.33***	-0.97***	-1.35***	-1.01***	2.34***	1.87***	2.42***	1.98***
	(-7.66)	(-5.39)	(-7.72)	(-5.59)	(6.70)	(5.14)	(6.96)	(5.49)
isldummy	-0.13*	-0.12*	-0.10	-0.09	0.45***	0.44***	0.35**	0.34**
	(-1.78)	(-1.68)	(-1.36)	(-1.29)	(3.14)	(3.07)	(2.41)	(2.37)
pisldummy	-0.12*	-0.11	-0.11	-0.10	0.42***	0.41***	0.37***	0.37**
	(-1.64)	(-1.55)	(-1.47)	(-1.41)	(2.89)	(2.83)	(2.57)	(2.53)
Ln*Y/cap*	-0.29***	-0.29***	-0.23***	-0.23***	0.41***	0.41***	0.16***	0.16***
	(-15.31)	(-15.36)	(-9.36)	(-9.36)	(8.62)	(8.64)	(2.92)	(2.90)
Lnp*Y/cap*	-0.36***	-0.36***	-0.28***	-0.28***	0.32***	0.32***	0.17***	0.17***
	(-18.98)	(-19.12)	(-11.56)	(-11.66)	(6.85)	(6.93)	(3.11)	(3.16)
ln*Inf*			0.32***	0.32***			-1.44***	-1.45***
			(3.47)	(3.59)			(-7.92)	(-7.99)
lnp*Inf*			0.50***	0.51***			-1.1***	-1.1***
			(5.54)	(5.60)			(-6.03)	(-6.06)
ln(1+*Inftran)*			0.21**	0.18*			-0.62***	-0.58***
			(2.13)	(1.81)			(-3.13)	(-2.91)
ln(1+p*Inftran)*			0.14	0.11			-0.4**	-0.36*
			(1.43)	(1.09)			(-2.02)	(-1.80)
Africa	0.08	0.09	-0.02	0.00	-0.23	-0.25	0.15	0.13
	(0.36)	(1.15)	(-0.26)	(0.00)	(-1.29)	(-1.43)	(0.86)	(0.71)
PAfrica	0.52***	0.53***	0.37***	0.39***	-0.59***	-0.62***	-0.31**	-0.34*
	(6.52)	(6.72)	(4.37)	(4.62)	(-3.46)	(-3.58)	(-1.78)	(-1.93)
AA	0.26*	-6.05***	0.22	-6.00***	0.76***	9.18***	0.88***	9***
	(1.79)	(-6.57)	(1.52)	(-6.54)	(2.61)	(4.92)	(3.03)	(4.89)
Aadistance		0.81***		0.80***		-1.08***		-1.04***
(ln(1000km))		(6.93)		(6.85)		(-4.56)		(-4.46)
Pseudo Rsq	0.47	0.48	0.48	0.49	0.79	0.79	0.8	0.8
σ	1.69	1.68	1.68	1.68	3.38	3.38	3.33	3.33
Africa factor	2.36		1.77		0.94		2.05	
Africa,(1000km)		1.18		0.92		2.34		4.98
Africa,(3000km)		2.87		2.21		0.71		1.59
Critical distance		826		1110		2196		4684

Notes: 1) N=4516; t-stats in parenthesis ; Pseudo Rsq given by the correlation of actual and predicted imports; constants included but not reported; σ is the standard error of the Tobit estimate.

2) All variables and sample selection as in table 2.

3) Africa factor= exp(africa+pafrica+AA), or exp(africa+pafrica+AA+AAdistance*ln(# km)). Critical distance, *x* given by: 1-exp(africa+pafrica+AA+AAdistance*ln(*x*))=0.

6. Summary and conclusions

Transport costs and trade volumes depend on many complex details of geography, infrastructure, administrative barriers, and the structure of the shipping industry. In this paper we have used several sources of evidence to explain transport costs and trade flows in terms of geography and the infrastructures of the trading countries, and of countries through which their trade passes.

Some of the main results on the impact of infrastructure are summarised in table 8, where changes are all reported from the median level of infrastructure. The results are strongly consistent, although they come from different data sets and measure different things. Thus, a deterioration in infrastructure from that of the median country to the 75th percentile raises costs, according to our shipping data, by an amount equivalent to 3466km of sea travel or 419km of overland travel. Using the cif/fob ratio, the equivalent distance is 2016km. The impact on trade volumes is equivalent to extra 1627km distance.

Table 8: Predicted effects of infrastructure on trade costs and trade volumes.

	Shipping data			Cif/fob		Gravity	
Infra-structure: percentiles	Transport costs US $	Sea km, equiv change	Land km, equiv change	Cif/fob ratio	Km, equiv change	Trade volume, % change	Km, equiv change
25th	4638	-3989	-481	1.11	-2358	+68%	-2005
Median	5980	0	0	1.28	0	0	0
75th	6604	+3466	+419	1.40	+2016	-28%	1627

Note: Shipping data from table 1, column 4; Cif/fob from table 2, column 4; gravity from table 3, column 4.

Linking transport costs to trade volumes, we estimate an elasticity of trade flows with respect to the transport cost factor of around –3. The implications of this are summarised in Table 9, and indicate, for example, how a doubling of transport costs (from the median value) reduces trade volumes by 45%.

Table 9: Predicted effects of transport cost factor on trade volumes, $\tau = -3$.

Transport cost factor, *t*, selected values	Predicted change in trade volume from median
1.11 (25th percentile)	+53%
1.14	+42%
1.28 (Median)	0
1.56	-45%
1.83 (75th percentile)	-66%

The paper also presents results on the disadvantages faced by landlocked countries and by African countries. From both the shipping and the cif/fob data sets, we see that landlocked countries are disadvantaged, the representative landlocked economy having transport costs 50% higher and trade volumes 60% lower than the representative coastal economy. However, landlocked countries are able to overcome a substantial proportion of this disadvantage through improvements in their own and their transit countries' infrastructure. Looking at Sub-Saharan Africa we see that transport costs are relatively high, and that trade flows are lower than would be predicted by standard gravity modelling both for intra-SSA trade and for African countries' external trade. We find that most of this poor performance is explained by poor infrastructure, and by a particular penalty on long distance (typically cross-continental) trade in Africa.

Shipping costs of the magnitudes reported in this paper have a major impact on income, both because of the direct cost they impose, and because of the gains from trade foregone. However, our results also point to the potential for reducing these costs though infrastructure investment.

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Appendix

Construction of variables:

Own Infrastructure: Each country's infrastructure is measured by an index constructed from four variables; kilometers of road, km of paved road, km of rail (each per sq. Km of country area), and telephone main lines per person. These measures are highly correlated among themselves and identifying each of their influences on transport costs separately is not possible. One possibility would have been to build an index using principal components. However, there are only 51 countries for which we have data on all of the measures. Thus we first normalize the variables to have the same mean, 1, and then take the linear average over the four variables, ignoring missing observations. This is equivalent to assuming that roads, paved roads, railways and telephone lines are perfect substitutes as inputs to a transport services production function. Taking the mean over the non-missing observations implicitly assumes that the missing take on average the same value as the non-missing variables. This measure was raised to the power –0.3. The reason for this is that infrastructure is an input to a transport services production function which, if Cobb Douglas, might be written as: $Y = K^{\alpha} L^{\beta} I^{\chi}$ where I, the index of infrastructure, is exogenous to the transport sector firm. Then for a given output the reduced form of the cost function will be $T = \phi\, I^{-\chi/(\alpha+\beta)}$ where ϕ is a function of the factor prices of private inputs, the technology and the target output. If there are constant returns to scale to the private inputs, *K* and *L*, then our assumption is that $\chi = 0.3$. According to the data this value implies that the transport cost per km of the worse infrastructure is approximately ten times that of the best one. In the log-linear specifications this scaling is only a choice of units.

Transit infrastructure: Let *L* denote a given landlocked country and L_t the set of transit countries *L* uses to reach the sea (table AIII). Ideally we weight transit countries' infrastructures by their share of the transit trade. However, available data reports solely whether a country is used for transit or not, so if country *L* uses *n* transit countries the variable inftran gives an equal weight of *1/n* the infrastructure index of each of those countries.

Two caveats that should be noted. First, we are assuming that no trade (or the same share of trade for all countries) goes by air. Although this is clearly unrealistic and the share of trade that is airborne is rising it is still small enough for landlocked countries to justify this assumption. Second, the transport cost from landlocked to neighbor countries should not include transit country costs and thus when necessary our variable is adjusted to reflect this fact.

Table AI

Variable	Description	Source	Use
Distance	Great circle distance between trading partners (1000's km unless ln is used).	Fitzpatrick (1986), authors' calculations	All
Distsea	Sea distance around continents from Baltimore to the sea port of landfall (1000's km) .	DMA (1985), authors' calculations	Shipping
Distland	Great circle distance from sea port of landfall to capital of destination (1000's km).	Authors' calculations	Shipping
Border	Dummy variable =1 if two countries are contiguous or are separated by less than 40 km, 0 otherwise.	CIA World Factbook	cif/fob, gravity
Inf	Inverse of the index of road, paved road and railway densities and telephone lines per capita. A higher value indicates worse infrastructure (see below for more details).	Canning 1998, authors' calculations	All
Inftran	Average value of infrastructure for the transit countries if a country is landlocked, zero otherwise. Table A III below lists the landlocked countries with respective transit countries used.	Canning 1998, UNCTAD, authors' calculations	All
ldldummy	Dummy variable =1 if the country is landlocked, 0 otherwise.	CIA World Factbook	All
isldummy	Dummy variable =1 if the country is an island, 0 otherwise.	CIA World Factbook	Gravity, cif/fob
T_{ij}	Cost of shipping a 40' container from i=Baltimore to country j (1000's US $, 1999). The mode is surface (as opposed to air), type is freight (as opposed to household goods) and packing is loose (as opposed to lift van where the cargo is packed into wooden containers). The cost does not include insurance.	Panalpina	Shipping
M_{ij}	Aggregate imports (inclusive of insurance and freight, cif)) of country j from country i 1000's current (1990) US$.	DOTS, IMF	Gravity
X_{ij}	Aggregate exports (free on board value) of country i to country j 1000's current (1990) US$.	DOTS, IMF	Gravity
t_{ij}	M_{ij} / X_{ij}	DOTS, IMF	Cif/fob
Y	GDP in current (1990) $US market prices.	WDI 1998	Gravity
Y/cap	Y/population	WDI 1998	All

Notes:

1) In the text ln*variable*: stands for the natural logarithm of *variable*, p*variable*: stands for the trade partner's *variable*.
2) There are 103 countries in the sample used in sections 2 and 3. This implies 10712 potential bilateral pairs. The sample is greatly reduced because 2759 of the pairs had missing import or export values, 555 had positive imports of j from i but exports of zero from i to j, 2494 had non-positive transport costs and 195 had cif/fob between 1.0909 and 1.101

Table AII

List of countries in different samples

(sorted by own infrastructure quality)

Shipping

Belgium
Netherlands
Switzerland
Austria
Italy
Germany
Hungary
Rwanda
Uruguay
Turkey
India
South Africa (25th)
South Africa
Thailand
Zimbabwe
Brasil
Chile
Swaziland
China
Malawi
Argentina
Senegal
Uganda
Kenya (50th)
Botswana
Cameroon
Togo
Ivory coast
Ghana
Nigeria
Congo
Paraguay
Tanzania
Bolivia
Peru
Lesotho (75th)
BurkinaFaso
Zambia
Benin
Nepal
Burundi
Bhutan
Mozambique
Mali
Central
Niger
Chad
Ethiopia*
Eritrea*
Georgia*
Russia*
Luxembourg*
CzechRepublic*
Azerbaijan*
Armenia*
Belerus*
Kazakhstan*
Kyrgyzstan*
Macedonia*
Moldova*
Slovakia*
Taijikstan*
Turkmenistan*
Uzbekistan*

Cif/fob and Gravity [1]

Belgium
Singapore
Netherlands
Switzerland
Japan
Hong Kong, China
Denmark
Austria
United Kingdom
Germany
Italy
France
Ireland
Hungary
Poland
Israel
Trinidad and Tobago
Portugal
Finland
Romania
Korea, Rep.
Rwanda
Greece
United Arab Emirates
Uruguay
United States (25th)
Mauritius
Spain
Sweden
Costa Rica
El Salvador
India
Turkey
New Zealand
Sri Lanka
Jamaica
South Africa
Norway
Mexico
Jordan
Argentina
Tunisia
Malaysia
Syrian Arab
Thailand
Panama
Bangladesh
Chile
Philippines
Brazil
Canada
Pakistan (50th)
Oman
Guatemala
Colombia
Zimbabwe
Venezuela
Gambia, The
Iran, Islamic Rep.
Honduras
Togo
Ecuador
Malawi
Saudi Arabia
Egypt, Arab Rep.
Indonesia
Australia
Uganda
China
Kenya
Paraguay
Dominican Republic
Senegal
Ghana
Burundi
Algeria
Cameroon
Nigeria (75th)
Cote d'Ivoire
Peru
Bolivia
Benin
Gabon
Sierra Leone
Haiti
Guinea
Guinea-Bissau
Zambia
Angola
Congo, Dem. Rep.
Nicaragua
Papua New Guinea
Congo, Rep.
Burkina Faso
Nepal
Lao PDR
Madagascar
Mozambique
Mauritania
Central African Republic
Mali
Niger
Chad

Notes:

1) Not all country pairs were used due to missing data.
2) Countries with an (*) were excluded from columns 3 and 4 in Table I in the text due to missing data for own or transit infrastructure.
3) 25th, 50th and 75th denote the countries with infrastructure values closest to these sample values.

Table AIII

List of landlocked countries' transit countries

(sorted by transit infrastructure quality)

Shipping [1]		***Cif/fob*** [2]	
Landlocked country	*Transit countries*	*Landlocked country*	*Transit countries*
Austria	Germany	Switzerland	Germany, Italy, Netherlands
Hungary	Germany	Hungary	Austria, Italy
Switzerland	Germany	Austria	Germany, Italy
Bhutan	India	Laos PDR	Thailand, Vietnam
Nepal	India	Zambia (25th)	Mozambique, Tanzania, South Africa
Botswana (25th)	South Africa	Zimbabwe (25th)	Mozambique, Tanzania, South Africa
Lesotho (25th)	South Africa	Nepal	Bangladesh, India
Swaziland (25th)	South Africa	Paraguay	Argentina, Brazil, Chile, Uruguay
Zimbabwe (25th)	South Africa	Bolivia	Argentina, Brazil, Chile, Peru
Zambia	South Africa, Zimbabwe	Central African Republic (50th)	Cameroon, Congo, Rep., Congo, Dem. Rep.
Paraguay (50th)	Brazil	Burundi	Kenya, Tanzania, Uganda
Bolivia	Chile	Mali	Burkina Faso, Cote d'Ivoire, Senegal
Malawi	South Africa, Zimbabwe	Rwanda	Burundi, Kenya, Tanzania, Uganda
Burundi	Kenya	Chad (75th)	Cameroon, Nigeria
Uganda	Kenya	Malawi	Botswana, Mozambique, Zambia, Zimbabwe
Rwanda (75th)	Kenya, Tanzania	Niger	Benin, Burkina Faso, Nigeria, Togo
Central African Republic	Cameroon	Burkina Faso	Cote d'Ivoire, Togo
Chad	Cameroon	Uganda	Kenya, Tanzania
BurkinaFaso	Cote d'Ivoire		
Mali	Cote d'Ivoire		
Niger	Benin		

Notes:

1) Transit countries coincide with the port of entry reported by the shipping company. In the case of Zambia and Malawi Zimbabwe is also a transit country. The countries for which there is no transit or own infrastructure data (see note 2 of table AII) are not included here since they were not used in the restricted sample.
2) Without specific knowledge of the source of the import and transit route we must take the average infrastructure measure over all the transit countries reported by UNCTAD (see table AI).
3) 25th, 50th and 75th denote the countries with transit infrastructure values closest to these percentile values.

Table AIV: Summary statistics:

Shipping: All data is for 1998

Variable	**Mean**			**Standard deviation**
	Sample n=64	Landlocked n=35	Coastal n=29	Sample n=64
T	6.59	8.21	4.62	3.5
Distance	9.58	9.76	9.37	2.39
Distsea	10.5	10.1	10.9	3.75
Distland	.979	1.5	0.353	1.27
Y/cap	4.01	3.57	4.56	8.11

Restricted sample (countries for which infrastructure data is available)

Variable	**Mean**			**Standard deviation**
	Sample n=47	Landlocked n=21	Coastal n=26	Sample n=47
T	5.98	7.95	4.38	3.49
Distance	9.75	10.2	9.37	2.6
Distsea	11.2	11.6	11	3.92
Distland	0.631	0.996	0.336	0.57
Inf	1.72	2.05	1.44	0.901
Inftran	0.604	1.35	0	0.729
Y/cap	4.21	3.54	4.76	8.24

Note: The infrastructure data is only available until 1995. Here the average from 1990 to 1995 is used, similarly for income.

CIF/FOB and Gravity: All data for 1990 (n=4615[1])

Variable	**Mean**	**Standard deviation**
LnM	2.89	2.80
Lnt	0.49	0.62
LnInf	0.23	0.47
LnInftran	0.11	0.29
Lndistance	8.49	1.54
Border	0.03	0.16
Isldummy	0.16	0.36
Ldldummy	0.15	0.36
Africa	0.26	0.44
AA	0.07	0.26
Aadistance	7.68	0.91
LnY	24.29	2.26
lnY/cap	7.8	1.66

Notes:

1) For AAdistance the statistics correspond to African partners only.
2) Similar statistics hold for the partner country variables.
3) See table AII for country sample.
4) LnM and lnt correspond to the uncensored values of the variables so the sample size is 3577 for those statistics.
5) The median for t is 1.28.

Table AIV: Summary statistics (ctd):

CIF/FOB and infrastructure: quartile values

Variable	25th percentile	50th percentile	75th percentile
Cif/fob (all sample)	1.11	1.28	1.83
Cif/fob (coastal)	1.10	1.29	1.82
Cif/fob (landlocked)	1.10	1.23	1.91
Inf (landlocked)	1.48	1.82	2.61
Inftran	1.18	1.37	1.59
Inf	0.95	1.41	1.81
Distance	4536	7555	10729
Distance (landlocked)	4078	6742	9922

Notes:
1) First two rows used in table 4.
2) All variables correspond to all country pairs in the sample except for first and last row which refer to landlocked importers only.

Figure AI

Transport cost of landlocked countries relative to an average coastal country

(predicted by cif/fob, Δ, and and shipping data, •).