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Infrastructure, Geographical Disadvantage, and Transport Costs

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The median landlocked country has only 30 percent of the trade volume of the median coastal economy Halving transport costs increases that trade volume by a factor of five Improving the standard of infrastructure from that of the bottom quarter of countries to that of the median country increases trade by 50 percent Improving infrastructure in Sub-Saharan Africa is especially important for increasing African trade.

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Summary findings

Limão and Venables use three different data sets to investigate how transport depends on geography and infrastructure. Landlocked countries have high transport costs, which can be substantially reduced by improving the quality of their infrastructure and that of transit countries.

Analysis of bilateral trade data confirms the importance of infrastructure. Limão and Venables estimate the elasticity of trade flows with regard to transport costs to be high, at about –2.5. This means that:

- The median landlocked country has only 30 percent of the trade volume of the median coastal economy.
- Halving transport costs increases the volume of trade by a factor of five.
- Improving infrastructure from the 75th to the 50th percentile increases trade by 50 percent.

Using their results and a basic gravity model to study Sub-Saharan African trade, both internally and with the rest of the world, Limão and Venables find that infrastructure problems largely explain the relatively low levels of African trade.

This paper — a product of Trade, Development Research Group — is part of a larger effort in the group to investigate the effects of geography on economic performance. Copies of the paper are available free from the World Bank, 1818 H Street, NW, Washington, DC 20433. Please contact Lili Tabada, room MC3-333, telephone 202-473-6896, fax 202-522-1159, email address ltabada@worldbank.org. Policy Research Working Papers are also posted on the Web at www.worldbank.org/research/workingpapers. The authors may be contacted at ng14@columbia.edu or avenables@worldbank.org. December 1999. (39 pages)

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Non-technical summary: Infrastructure, Geographical Disadvantage and Transport Costs

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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. Recent liberalizations have reduced artificial trade barriers, and mean that the effective rate of protection provided by transport costs is, for many countries, considerably higher than that provided by tariffs. 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.

This paper studies the determinants of transport costs, and shows how they depend both on countries' geography, and on their levels of infrastructure (measured by an index combining road, rail and telecommunications density). Our research uses three data sets. 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 the city of origin, the city of landfall, and the final destination city. The disadvantages are that it is not clear how the experience of Baltimore generalizes, since charges are affected by the particular routes, frequencies, and opportunities for back-hauling and for exploiting monopoly power that are present. Our second data set uses the cif/ fob ratios reported for each country by the IMF. These are representative, in so far as they cover the entire imports of each reporting country. However, there are some questions regarding the quality of the data, and the measure suffers from the fact that it is an aggregate over all commodity types imported. Our third piece of analysis uses bilateral trade data in a gravity modeling exercise, adding to the standard independent variables our measures of geography and infrastructure.

Our main results are, first, that infrastructure – both own infrastructure and that landlocked countries' transit routes -- is a significant and quantitatively important determinant of transport costs and of bilateral trade flows. For example, improving destination infrastructure by one standard deviation reduces transport costs by an amount equivalent to a reduction of 6,500 sea km or 1,000km of overland travel.

Second, being landlocked raises transport costs by around 50% (for the median landlocked country compared to the median coastal economy). However, improving the infrastructure of the landlocked economy from the median for landlocked economies to the 25th percentile reduces this disadvantage by 12 percentage points, and improving the infrastructure of the transit economy by the same amount reduces the disadvantage by a further 7 percentage points.

Third, combining estimates from transport cost data with the trade data we are able to compute the elasticity of trade with respect to transport costs; it is high, at around –2.5. This means that the median landlocked country only has 30% of the trade volume of the median coastal economy. Improving infrastructure to the 25th percentiles raises this to over 40%.

Finally, we use our results to study Sub-Saharan African trade. While a basic gravity model suggests that African trade, both internally and with the rest of the world, is lower than would be predicted, augmenting the model to include infrastructure moves the predicted values much closer to the actual. Most of Africa's poor trade performance can be accounted for by poor infrastructure.

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] Recent liberalizations have reduced artificial trade barriers, and now mean that the effective rate of protection provided by transport costs is, for many countries, considerably higher than that provided by tariffs.[2] 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 the goal of this paper.

This paper studies the determinants of transport costs, and shows how they depend both on countries' geography, and on their levels of infrastructure. The geographical measures we focus on are distance between countries, whether or not they share a common border, and whether they are landlocked or islands. The infrastructure measures relate to the quality of transport and communications infrastructure they possess. 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.[3] We show that infrastructure is quantitatively important in determining transport costs, a finding with important policy implications for infrastructure investment. For example, improving own and transit countries' infrastructure from the 25^{th} percentile to the 75^{th} percentile overcomes approximately two-thirds of the disadvantage associated with being landlocked.

Our research uses several different data sets. 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 the city of origin, the city of landfall, and the final destination city. The disadvantages are that it is not clear how the experience of Baltimore generalizes, since charges are affected by the particular routes, frequencies,

[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] 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 (1998) for recent data on nominal rates for the U.S., New Zealand, Argentina and Brazil.

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

and opportunities for back-hauling and for exploiting monopoly power that are present. Our second data set uses the cif/ fob ratios reported for each country by the IMF. These are representative, in so far as they cover the entire imports of each reporting country. However, there are some questions regarding the quality of the data, and the measure suffers from the fact that it is an aggregate over all commodity types imported.

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 modeling exercise, incorporating the same geographical and infrastructure measures that we use estimating trade costs. This strongly confirms the importance of these variables in determining trade, and also enables to compute estimates of the elasticity of trade flows with respect to transport costs. We find that this elasticity is extremely large, with a doubling of transport costs typically reducing trade flows by more than 80%.

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 also 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 much 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 75^{th} percentile to the 25^{th} 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 combine the results of the previous sections to derive a bilateral transport cost matrix which is used to analyze trade and transport costs in Sub-Saharan Africa.

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. We suppose that it is determined by:

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

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. The first is whether the countries share a common border, which we take to be cost reducing, and the second is the shortest direct distance between countries, as is standard practice in the literature. 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 telephones 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 appendix I.[4]

2.2 Shipping from Baltimore:

[4] Three important country characteristics we do not analyze are the existence of agreements between landlocked and transit countries, the efficiency and transparency of customs procedures and the market structure of transport services facing different countries, the last two due to lack of data.

Our first results are based on the costs of shipping a standard 40' container from Baltimore to different destinations around the world[5]. 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 is given in table 2, appendix I).

This source of data has two major advantages. The first is that it enables us to break journeys 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 second 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:

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

where i corresponds to Baltimore in the U.S. 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 which 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. Therefore table 1 presents the OLS estimation results of the linear form given by equation (*2*):

[5] The data refers to the cost of shipping a 40' container; 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.

[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 reduced size of the sample in both studies does not allow for a systematic examination of the determinants of transport costs.

Table 1:
Cost (Thousand US $, 1998) of shipping 40' container from Baltimore
Dependent variable: Transport cost (T_{ij})

	1	2	3	4
Inf			1.31**	1.56*
			(2.51)	(2.92)
Inftran			1.34**	0.67
			(1.93)	(0.88)
Idldummy	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.Distance and Idldummy are for 1998. The infrastructure variables used 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. Idldummy=1 if the country has no access to the sea, 0 otherwise
2)***,**,* indicates significance at 10%, 5% and 1% 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 s.e. errors were adjusted to correct for heteroskedasticity.

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 the mean cost for non-landlocked countries of $4,620. Second, breaking the journey into an overland and sea component considerably improves the fit of the equation, and gives a much larger coefficient for the overland portion of the trip[7]; an extra 1000 km by sea adds $190 whereas a similar increase in land distance adds

[7] This is true even when quadratic terms are added to capture any non-linearity. These terms are insignificant further justifying the use of the linear land and sea distance measures.

$1,380. When this value is compared to the $380 per 1000km predicted by straight line distance it becomes clear that using the latter measure leads to a large underestimate of the impact of 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].

Columns 3 and 4 introduce our measures of the inverse infrastructure of the destination (*inf*) and, for landlocked countries, the transit country (*inftran*). The signs of these are as would be expected, inferior infrastructures leading to higher transport costs. Improving destination infrastructure by 1 standard deviation reduces transport costs by around $1,200 (compared to a mean of $5,980), equivalent to reducing distance by around 6,500 sea km, or 1,000 land km. The final specification (column 4) also 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), although splitting the distance variable makes the coefficient for transit infrastructure smaller and insignificant. The reason for this is the variable's high positive correlation with land distance. Moreover transit and own infrastructure are also highly correlated (an issue that will be further addressed below). 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.[9]

[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).

[9] We experimented with some further analysis of this data. 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 (for example, the costs of shipping from Baltimore to Durban, as well as the costs of shipping 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 turns out to be significant and positive, but neither distance nor port infrastructure are significant in this estimation. This is due not only to the small number of observations but also to some finer details that become apparent upon inspection of the data. For example, we see that shipping from Baltimore to Durban costs $2,500, and shipping the 1,600 further Kms to Lusaka an additional $2,500, whereas the 347 Kms from Durban to Maseru (Lesotho) cost an additional $7,500. This simply points to the importance of the fine details of geography, market structure and size in addition to the broader picture painted by the econometrics.

2.3 Cif/fob measures

Our second set of experiments is based on the cif/fob ratio as reported by the IMF.[10] The ratio gives, for each country, the value of imports inclusive of carriage, insurance and freight, relative to their free on board value, the cost of the imports and all charges incurred in placing the merchandise aboard a carrier in the exporting port. The ratio cif/fob - 1 represents the ratio of unit transport costs to the fob price and thus provides a simple summary statistic of the transport cost *rate* on imports.

The advantage of the cif/fob measure is that we have data for more countries than are in the shipping data. However, it has several drawbacks. The first is measurement error; the cif/fob factor is calculated for those countries that report the total value of imports at cif and fob values, both of which involve some measurement error. Moreover not all countries report these every year and thus some of the values the IMF reports for 1990 appear not to have been updated.[11] The second concern is that the measure aggregates over all commodities imported, so it is biased if high transport cost countries systematically import lower transport cost goods. This would be particularly important if we were using exports, which tend to be concentrated in a few specific goods. It is less so for imports which are generally more diversified and vary less in composition across countries.[12] Finally, the measure aggregates over the different sources of supply, so for each importer there is a single cif/fob measure, not a full set of cif/fob measures for imports from each supplying country. Correspondingly, when we construct variables describing the characteristics of each country's import suppliers we have to construct a single average measure, which we do by constructing import weighted shares. We use bilateral trade data to do this, so, for example, for each country we construct the import weighted average distance of its supplying countries.

Given concerns about the quality of the cif/fob data we perform several comparisons of the results obtained using this data with those using the shipping cost data (the comparisons are in sections 4 and 5.1). They confirm that the cif/fob data does contain information about the cross sectional variation in transport costs, and that results from using this data are quite consistent with those obtained from the shipping cost data.

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

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[10] IFS (1995) using values for 1990. See appendix table 1 for data sources.

[11] For an early description of the problems with this data see Moneta (1959).

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

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 are rarely border prices, instead measuring the prices at the initial point of departure and final destination respectively[13]. Thus own and partner infrastructure should be included in the estimation.

Denoting the true transport cost *rate* between i and j by t_{ij} and the fob price of a given good shipped from i to j by p_{ij} we have

$$\begin{aligned} t_{ij} &\equiv T_{ij} / p_{ij} \\ t_{ij} &= t\ (x_{ij}, X_i, X_j, \tilde{\mu}_{ij}) \end{aligned} \tag{3}$$

where the second equation uses the determinants of T_{ij}, given in (1), and assumes that the determinants of p_{ij}, other than x_{ij}, X_i and X_j, are uncorrelated with the explanatory variables. Since we do not have data on the bilateral transport cost rates we aggregate *(3)* over all of country j's partners by taking logarithmic averages and using import shares, s_{ij}, as the weights. Assuming that t can be approximated by a loglinear function up to some measurement error we have the average observed transport cost rates t_j as:

$$\begin{aligned} \ln t_j &= \sum_i s_{ij} \ln t_{ij} + \omega_j \\ \ln t_j &= \tilde{\alpha} + \tilde{\delta}' \ln X_j + \tilde{\beta}' \sum_i s_{ij} \ln x_{ij} + \tilde{\gamma}' \sum_i s_{ij} \ln X_i + \omega_j \end{aligned} \tag{4}$$

where the tildes distinguish this set of parameters from the partial effects of the measures on transport cost per unit, T, estimated in the shipping section. In terms of the data, t_j corresponds to the ratio cif/fob – 1 for importing country j.[14]

Before proceeding two comments are in order, one on the functional form assumed for *(3)* and the other on the effects of the weighting of partner characteristics. As in the shipping section the 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, e.g. if country j does not have a container

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

[14] Recall that X_i refers to a k_ix1 column vector and β to a conformable row vector of coefficients, where k_i is the number of explanatory variables used for partner countries, similarly for x_{ij} and X_j.

port country then i will not benefit from its own container facilities in exporting to j.[15] We found that the loglinear form fitted the data considerably better than the linear one.

The weighting of partner characteristics will imply that the coefficients for those variables will in general not be unbiased estimates of the corresponding coefficients of t_{ij}, the bilateral transport cost rate function. This is because of correlation between the weighted variables and the error term introduced when weighting by the shares and the fact that the shares may themselves be a function of the transport cost rate. It is not possible to determine the sign of the bias. The endogeneity could in principle be resolved if a form of the gravity equation was estimated jointly and population or area were used as instruments, but the weighting would still have to be used given the data constraints. As we will see the issues above do not do much damage to our estimates of own and transit elasticities for which we obtain results that are strikingly similar to the ones in the shipping section.

Estimation results

The results from the estimation of (*4*) are given in table 2. The first three rows of the table are importing country characteristics; the log of its infrastructure (ln*inf*); if it is landlocked, that of its transit country (or average when there is more than one), ln(1+*inftran*); and a landlock dummy (*ldldummy*). The next four rows give average trading partner characteristics, with notational convention *wvariable* = $\Sigma_i s_{ij}$ *variable*, i.e. partner variables weighted by their shares in country j imports. We have the import share weighted sum of the log of distance, (wln*distance*), partner infrastructure (wln*pinf*), partners' transit countries' infrastructure (wln(1+*pinftran*)), and the share of imports from countries with which j shares a common (w*border*). The last two rows are dummy variables for country j being an island, and the share of imports coming from islands

The results in table 2 show that poor own and partner infrastructure (ln*inf* and wln*pinf*) increase transport costs significantly, as expected. Transit country infrastructure (ln(1+*inftran*)) has a similar effect, although multicollinearity with the landlock dummy and common border variable is a problem, making it difficult to disentangle the individual effects of explanatory variables and leading to high standard errors. Although average distance is significant and cost increasing when the only other regressor is a landlocked dummy (column 1) it becomes statistically insignificant when own infrastructure is added. However, the inclusion of the infrastructure measures explains more than twice as much of the variation in t_j than does the basic specification using distance and a landlocked dummy

[15] 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}.

alone. The trade weighted average of the trading partners' transit countries infrastructures has the right sign, but is not significant. Being an island or having a high share of imports from islands reduce transport costs (column 4) but the effects are insignificant.

The most important message from table 2 is the importance of infrastructure in determining transport costs. Own infrastructure and transit partner infrastructure are both significant, with an increase of one s.e. in own and transit infrastructure raising t_j by approximately 19% and 14% respectively. The trade weighted average of partner infrastructures is also significant, and a one s.e. increase in this variable raises t_j by 15%. We return to these results in section 4, where we compare them with results from our other approaches.

Table 2
Average transport cost rate (1990)
Dependent variable: ln Transport cost *rate* (ln t_j)

	1	2	3	4
ln*inf*		0.72^{*}	0.47^{*}	0.42^{*}
		(4.81)	(3.60)	(3.06)
ln(1+*inftran*)		0.11	0.43^{**}	0.43^{*}
		(0.61)	(2.63)	(2.62)
ldldummy	0.29^{***}			
	(1.70)			
*w*ln*distance*	0.34^{*}	0.07	-0.08	-0.034
	(3.45)	(0.70)	(-0.984)	(-0.36)
wborder			-1.97^{*}	-2.03^{*}
			(-6.44)	(-6.44)
wln*pinf*		1.55^{**}	1.74^{*}	1.64^{*}
		(2.48)	(3.34)	(3.02)
wln(1+*pinftran*)		2.96	1.96	1.37
		(1.08)	(0.86)	(0.58)
Isldummy				-0.074
				(-0.50)
wisldummy				-0.50
				(-1.08)
Constant	-2.72^{*}	-2.51^{*}	-2.0^{*}	-1.93^{*}
	(-22.3)	(-17.2)	(-13.8)	(-12.4)
N	98	98	98	98
Adj. R^2	0.12	0.33	0.53	0.53
F-tests (p-values)				
ln*Inf*, wln*distance*	-	0.00	-	-
ln*Inf*, ln*Inftran*	-	0.00	-	-
wbor, wln*distance*	-	-	0.00	0.00

Notes:
1) All variables are for the year 1990; *isldummy*=1 if country is an island, 0 otherwise; $wvariable=\Sigma_i s_{ij} variable$. The import shares, s_{ij}, were calculated using U.N. data from the Commtrade database (see Appendix I for more details). The original transit variable, *Inftran*, ranges from 0 for the coastal economies to approximately 1.7. Thus, 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 multiply the coefficient of ln*Inftran* by *Inftran /(1+ Inftran)*. This ratio ranges from 0.42 to 0.63 for landlocked countries.
2) ***,**,* indicates significance at 10%, 5% and 1% 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. Trade volumes:

Instead of looking directly at trade costs we now look at the trade flows they support, and do this by estimating a gravity model including the infrastructure variables we have used above. There are several reasons for doing this. First, trade data is much richer than transport cost data – we use the bilateral trade data for 93 countries. Second, the variables we have 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. And third, 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. Although its empirical use in the context of international trade dates back to the early 60's the theoretical underpinnings were not developed until much later[16]. Despite the abundant number of theoretical derivations of the gravity equation the majority of them does not model transport costs explicitly, two exceptions are Bergstrand (1985) and Deardorff (1997). More recently, in independent work, Bougheas et. al (1999) incorporate transport infrastructure in a two country Ricardian model and show under what circumstances it affects trade volumes[17].

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

$$M_{ij} = \varphi Y_j^{\phi_1} Y_i^{\phi_2} t_{ij}^{\tau} \quad or$$
$$\ln M_{ij} = \phi_0 + \phi_1 \ln Y_j \;\; + \phi_2 \ln Y_i \;\; + \;\; \tau[\tilde{\delta}' \ln X_j + \tilde{\beta}' \ln x_{ij} + \tilde{\gamma}' \ln X_i] + \eta_{ij} \qquad (5)$$

where the second equality is obtained by taking logs and substituting out the true transport cost rate for its determinants in the form used to derive equation (4) in the cif/fob section. We estimate this equation in the form:

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

17 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 these have a positive partial correlation with bilateral exports. However, the relevant measure for transport costs is infrastructure density and/or quality not the stock.

$$\ln M_{ij} = \phi_0 + \phi_1 \ln Y_j + \phi_2 \ln Y_i + \phi_3 \ln Distance_{ij} + +\phi_4 border_{ij} + \phi_5 isldummy_j + \phi_6 isldummy_i + \phi_7 \ln Inf_j + \phi_8 \ln Inf_i + \phi_9 \ln(1 + Inftran_j) + \phi_{10} \ln(1 + Inftran_i) + \eta_{ij} \quad (5')$$

where M_{ij} represents country j's imports from i valued at cif, Y_i is nominal GDP and the remaining variables are the same introduced in the shipping and cif/fob sections.[18]

Econometric issues and data

The model is estimated with 1990 data for a sample of 93 countries using two different approaches. The most common estimation technique for gravity equations is to perform OLS on the double log specification as given by equation *(5')*. This requires that the zero trade observations be dropped or somehow adjusted.[19] Given that the reason two countries do not trade may be precisely because they have high transport costs (or low incomes) dropping them amounts to a non-random selection of the data leading to biased estimates of the coefficients. In our case this is an important concern given that only 73% of the data records positive flows, and the issue is even more relevant for landlocked countries where approximately half the observations are positive. (We will see that one of the largest differences in the coefficients between the OLS and Tobit is for partner transit infrastructure). The correct procedure to account for this problem is to employ Tobit estimation.[20]

We assume that country *j*'s imports from *i* (in thousands $'s) will be determined by their trade potential given by the R.H.S. variables of *(5')* for values above 1. Otherwise we assume they have an arbitrarily small amount of trade. The exact maximum likelihood estimated can be found in appendix III. Maximum likelihood estimates were obtained using the Newton-Raphson method.

Estimation results

Table 3 contains the results of the estimation. The first column presents the OLS estimates for the baseline case which excludes the infrastructure variables. These are the standard regressors, incomes and distance along with the geographical variables: border and island dummies. The coefficients on income and distance are similar to those usually found when using OLS. Turning to the baseline results from the Tobit we note that the geographical variables enter as would be expected: coefficients on income rise, essentially because a high proportion of the zero trades involve low income countries.

[18] 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 $(1+Inftran_j)*(1-border_{ij})$ not $(1+Inftran_j)$ similarly for i.

[19] For example Linnemann (1966) and Wang and Winters (1991) add an arbitrarily small number before taking logs.

[20] Other authors that have used Tobit estimation in this context include Foroutan and Pritchett (1993) and Soloaga and Winters (1999).

The second and fourth columns add the infrastructure measures. The striking result is the strong performance of the infrastructure variables used in the preceding analysis. The infrastructures of importing and exporting countries enter as they should. Likewise, if either the importer or exporter is landlocked, then the transit country's infrastructure affects trade flows significantly, and with the correct sign.

A formal test of the restriction that the infrastructure coefficients are zero, i.e. do not belong in *(5')* strongly rejects that hypothesis. Moreover the large changes in the coefficients estimated in the baseline case suggest that these will be biased if the infrastructure variables are excluded. The distance elasticity, which is usually taken as the proxy for transport costs, falls by about 0.14 (corresponding to 3 s.e.) showing that it does indeed proxy for transport costs and not just information costs which are also bound to increase with distance. The most dramatic change however is in the income coefficients. These fall by over 12 s.e., thus some of the trade flows that have typically been attributed to the mass of the countries are actually due to lower trade costs explained by the fact that countries with higher GDP have bigger and better infrastructures and thus lower transport costs.[21]

So, the importance of including the infrastructure measures is not only that they increase the predictive power of the gravity estimates but that they eliminate the omitted variable bias in the baseline regressions and show the impact on trade of an important policy variable (more on the quantification below). Moreover, as we will show next, the gravity estimates contain valuable information about the coefficients of the bilateral transport cost rate function t_{ij}.

[21] The simple correlation between ln*GDP* and ln*inf* is –0.68.

Table 3

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

	OLS		*Tobit*[5]	
	Baseline	With infrast.	Baseline	With infrast.
ln*Distance*	-1.11*	-1.01*	-1.34*	-1.20*
	(-31.7)	(-29.0)	(-25.7)	(-23.4)
ln*Y*	0.97*	0.85	1.4*	1.20*
	(84.1)	(56.3)	(84.9)	(54.3)
ln*pY*	1.08*	0.98*	1.70*	1.46*
	(90.2)	(63.3)	(101.3)	(65.8)
border	1.02*	1.20*	0.55**	0.71*
	(6.16)	(7.28)	(2.21)	(2.91)
isldummy	0.35*	0.25*	0.58*	0.42*
	(5.04)	(3.67)	(5.77)	(4.17)
pisldummy	-0.010	-0.044	0.301*	0.17***
	(-0.15)	(-0.65)	(2.98)	(1.69)
ln*Inf*		-0.73*		-1.23*
		(-10.0)		(-11.8)
ln*pInf*		-0.78*		-1.40*
		(-10.7)		(-13.4)
ln*(1+Inftran)*		-0.67*		-1.02*
		(-7.21)		(-8.12)
ln*(1+pInftran)*		-0.32*		-0.86*
		(-3.28)		(-6.78)
N	6236	6236	8556	8556
Adj. R^2	0.69	0.70	-	-
Pseudo R^2	-	-	0.22	0.23
σ	-	-	3.18	3.08

1) All data for 1990
2) ***, **,* indicates significance at 10%, 5% and 1% respectively. t-statistics in parenthesis. Constant included in all specifications but not reported.
3) Pseudo $R^2 = 1 - L_1/L_0$ Where L_1 is the log likelihood value of the model when all the regressors are included whereas L_0 corresponds to the likelihood with constant term only. This is not directly comparable to the OLS R^2. σ gives the standard error of the Tobit estimate, see Appendix III for details.
4) The original transit variables, *Inftran*, ranges from 0 for the coastal economies to approximately 1.7. Thus, 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* by *Inftran /(1+ inftran)*. This ratio ranges from 0.40 to 0.63 for landlocked countries in this sample. The same applies to *pInftran.*
5) The Tobit coefficients correspond to the ϕ's in *(5')*.

4. Comparison and quantification

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

4.1 The cost of being landlocked

Table 4 gives the disadvantage of being landlocked, relative to being a median 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 58% 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 46%; improvement by the transit cuts the penalty to 51%, and if both improvements are made, the penalty drops to 39%. The second part of the table is based on the cif/fob measure. This gives somewhat smaller cost penalties, with the median landlocked economy experiencing transport costs 42% higher than the median coastal economy. Improving own and transit country infrastructure to the 25th percentile reduces this penalty to 32% and 36% respectively, and if both are improved the penalty drops to 26%.

Comparison of these results assures us that the estimates from our different data sources are consistent. The cif/fob data predicts relative costs about 16 percentage points lower than the shipping data at the median infrastructure values perhaps because of the use of import shares in the weighting of partner characteristics. But, most importantly for our purposes, the partial effects of the own and transit infrastructure variables are very similar across the data sets as is clear from the plots in Figure I in the appendix. These plots have two implications for the reliability of the cif/fob results in section 2.3. First, they indicate that the weighting of partner variables turns out to be relatively unimportant for the own and transit infrastructure coefficients. Second, the variation of the cif/fob measure explained by the infrastructure variables does reflect some information contained in that series regarding transport costs.

Table 4: The cost of being landlocked.

Transport costs of landlocked economy relative to mean coastal economy: Shipping data

		Own Infrastructure Percentiles		
		25th	Median	75th
Transit Infrastructure Percentiles	25th	1.39	1.51	1.66
	Median	1.46	1.58	1.73
	75th	1.55	1.67	1.83

Transport costs of landlocked economy relative to mean coastal economy: cif/fob data

		Own Infrastructure Percentiles		
		25th	Median	75th
Transit Infrastructure Percentiles	25th	1.26	1.36	1.65
	Median	1.32	1.42	1.73
	75th	1.36	1.47	1.78

Trade volume of landlocked economy relative to mean coastal economy:

		Own Infrastructure percentiles		
		25th	Median	75th
Transit Infrastructure Percentiles	25th	0.41	0.32	0.21
	Median	0.38	0.30	0.19
	75th	0.34	0.27	0.17

Notes:
1) The construction of the variables for the first two blocks of the table is as follows: We calculate the mean predicted transport cost (or cost rate for the cif/fob) over the landlocked countries allowing *inf* and *inftran* to vary but keeping all other variables at their landlocked mean. This is then divided by the mean predicted transport cost (or rate for the cif/fob) over the coastal countries. For the last block a similar procedure is used but the income levels used are the same for both landlocked and coastal countries so that only the transport cost factors vary.
2) The specifications used are column 3 table 1, column 5 table 2 and the last column in table 3.
3) The percentiles are taken over the landlocked countries sample.

The bottom part of the table undertakes an analogous experiment for trade volumes, asking how the volume of trade of representative landlocked economies compares with the median 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 30% the trade volume. Once again, trade volumes depend on own and transit infrastructure exactly as would be expected, with improvements in own infrastructure from the median to the 25th percentile increasing the volume of trade by 8 percentage points, improvement in transit country infrastructure increasing the volume by 2 percentage points, and a simultaneous improvement leading to an increase of 11 percentage points in the volume of trade.

4.2 The elasticity of trade with respect to transport costs.

It is natural to link trade volumes to transport costs by computing the parameter τ, the elasticity of trade volumes with respect to transport costs. We do this by using the estimates from the gravity and cif/fob models. Equations (*4*) and (*5*) provide over-identifying restrictions for τ, eight in total, one for each of the determinants in the transport cost equations. Given the potential for bias in the weighted variable coefficients in the cif/fob equation we focus on the unweighted and significant variables, own and transit infrastructure. The parameter estimates for these variables are given in table 5, and the ratio of the gravity to the cif/fob elasticities gives the elasticity of trade with respect to transport costs, as given in the last column.

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

	cif/fob elasticities[3] $\tilde{\delta}$		Gravity elasticities[4] ϕ		Import elasticity $\tau = \phi / \tilde{\delta}$	
	Inf	*Inftran*	*Inf*	*Inftran*	*Inf*	*Inftran*
Point	0.42	0.43	-1.23	-1.02	**-2.95**	**-2.34**
Min	0.15	0.11	-1.43	-1.61	-9.81	-15.25
Max	0.69	0.76	-1.02	-1.20	-1.49	-1.57

Notes:
1) Min and max correspond to the 95% confidence interval values for the cif/fob and gravity estimates.
2) The point estimate calculated from own infrastructure, -2.95, was used in the calculations for the predicted transport costs
3) cif/fob elasticities correspond from column 6 table 2
4) Gravity elasticities from Tobit estimation, last column table 3

The elasticities implied by the point estimates of either of these measures is very similar, being –2.95 on the basis of the own infrastructure measure, and –2.34 for the transit infrastructure measure. A simple test to check if the estimates are consistent with each other was done and failed to reject their equality. The message is that doubling the transport cost rate leads to a fall in import value between 5 and 6 times.[22]

These calculations and the comparison with results of previous studies assure us that the results obtained in the different sections of the paper are rather consistent. Not just in the predictive power of our set of transport cost variables but in the actual estimation of the parameters of the underlying transport cost equation. We now use them to estimate a bilateral transport cost matrix and apply it to investigate intra-African transport costs and their impact on trade.

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

Our results show how damaging poor infrastructure and landlockedness are to trade. Let us extend the quantitative implications of our findings by applying them to Sub-Saharan African (SSA) trade. We proceed in two stages. First, we use the gravity model together with actual SSA trade flows to predict trade costs on SSA trade – both intra-SSA and with rest of the world. This shows how much higher African trade costs are than those of other regions. Second, we address the question, is African trade 'too low'? The answer is that low trade levels are largely explained by infrastructure and geography.[23,24]

5.1 Predicted trade costs:

We use our gravity model, as outlined in equations (5) and (5') to produce predictions of trade costs between pairs of countries. Formally, this involves computing predictions $\hat{t}_{ij}$ up to a constant from the equation:

$$\ln \hat{t}_{ij} = \frac{1}{\hat{\tau}}\Big[\hat{\phi}_3 \ln Distance_{ij} + \hat{\phi}_4 border_{ij} + \hat{\phi}_5 isldummy_j + \hat{\phi}_6 isldummy_i + \\ + \hat{\phi}_7 \ln Inf_j + \hat{\phi}_8 \ln Inf_i + \hat{\phi}_9 \ln(1 + Inftran_j) + \hat{\phi}_{10} \ln(1 + Inftran_i)\Big] \quad (6)$$

22 This way of estimating τ is similar to the method used by Geraci and Prewo (1977) for 18 OECD countries for which they have bilateral transport cost rates. They find elasticity estimates in the range from -.27 to –2.6, slightly lower (in absolute value) than the ones we find, possibly because of different functional form and the restriction of their sample to high income countries.

23 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 SSA's net insurance and freight payments, according to balance of payments statitics, amounted to 15% of their exports' value. By comparison for all developing countries the payments averaged 5.8%.

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

Where the estimated coefficients are the ones from the last column in table 3 and the elasticity used is the one derived in the previous section from own infrastructure. Results are more readily interpretable if expressed in $ units, so we take the cost of shipping from Baltimore to Belgium as the reference point to scale these predicted values. Predicted values can then be interpreted as the $ cost of shipping a container between locations *i* and *j*. (In most of what follows it is the cross journey comparisons that are interesting, so the reader can dispense with this choice of units if comparative information is all that is needed).

To assess the reliability of these figures we took the predicted costs from US importers and compared them to the actual data for shipping costs from Baltimore. If the predicted variable is indeed a good approximation of nominal transport costs we would expect to find a large positive correlation (bearing in mind that the shipping data is for a later date and therefore some of the transport cost determinants may have changed slightly). We find a simple correlation of 0.62 between the two variables (we get the same correlation if we use the relative costs from (6) directly instead of the nominal values). Figure II in the appendix plots the constructed transport cost vs. the shipping data. This assures us that the predicted cost variable contains useful information which we now explore for Sub-Saharan Africa.

5.2 Intra-African trade costs

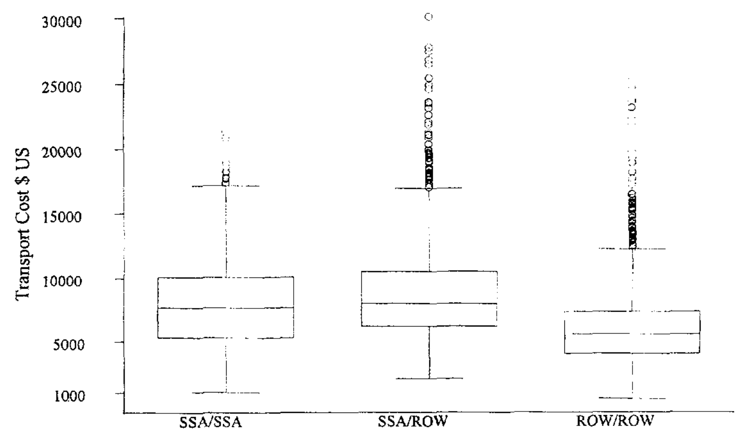
To compare the predicted transport costs facing intra-African trade with those in other regions we first plot in figure 1 the distribution of costs by location of importer and exporter. In figure 1a the first category refers to intra-African trade, the second for SSA imports from the rest of the world (ROW) and the third for imports to/from all countries excluding SSA. The line in the center of the box represents the median and the extremes of the box represent the interquartile ranges (25^{th} and 75^{th} percentiles). Two results stand out: first the median of transport costs for intra-SSA trade, $7,600, is almost the same as for SSA imports from the ROW and it is over $2,000 higher than for trade elsewhere (intra-ROW trade). Second the median of intra-SSA costs stands at about the 75^{th} percentile for the intra-ROW costs. Figure 1b compares the intra-SSA costs with those of other regions. The contrast is remarkable, the median transport cost for all other regions is below $5,000 i.e. below the 25^{th} percentile for SSA. Trade among countries in each of these groups, viz. Latin America and the Caribbean, East and South Asia and Middle East and North Africa does indeed have a natural advantage in terms of lower transport costs when compared to intra-African-trade.[25] Finally figure 1c

[25] The median cost for these regions is respectively $4,600, $3,900 and $2,100.

shows that the median cost of trade between SSA and the U.S., Japan or Germany is cheaper, or at least no more expensive, than the median intra-SSA trade cost.

Figure 1
Relative African Transport costs (Boxplots by location of importer/exporter)

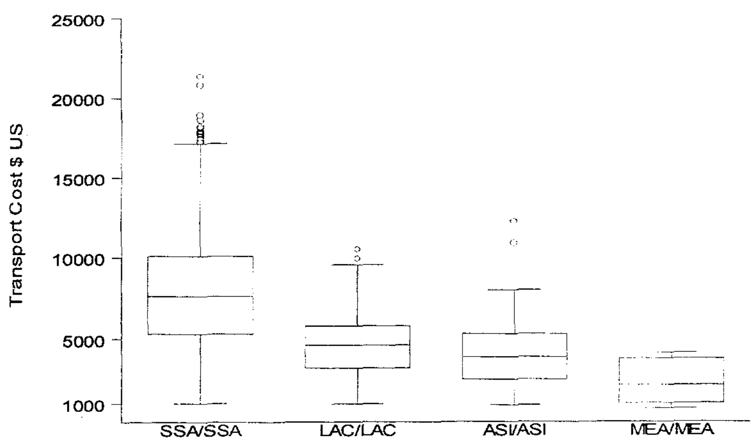
1 a. SSA vs. ROW



Legend

SSA: Sub-Saharan Africa
ROW: Rest of the World

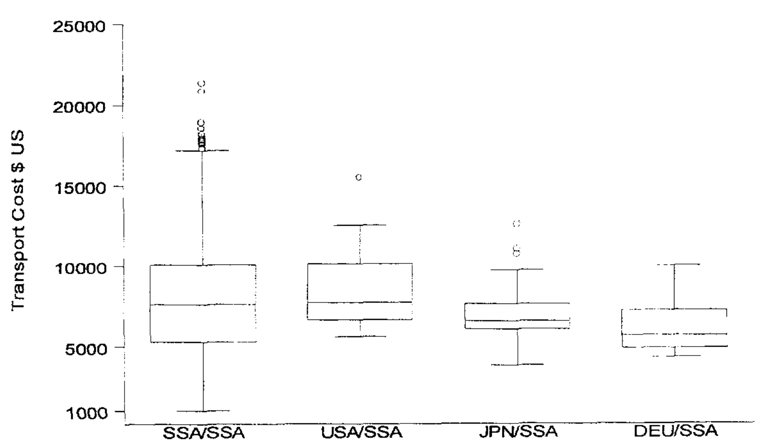
1 b.SSA vs. other Regional Groups



Legend

LAC: Latin America and Caribbean
ASI: South and East Asia
MEA: Middle East and North Africa

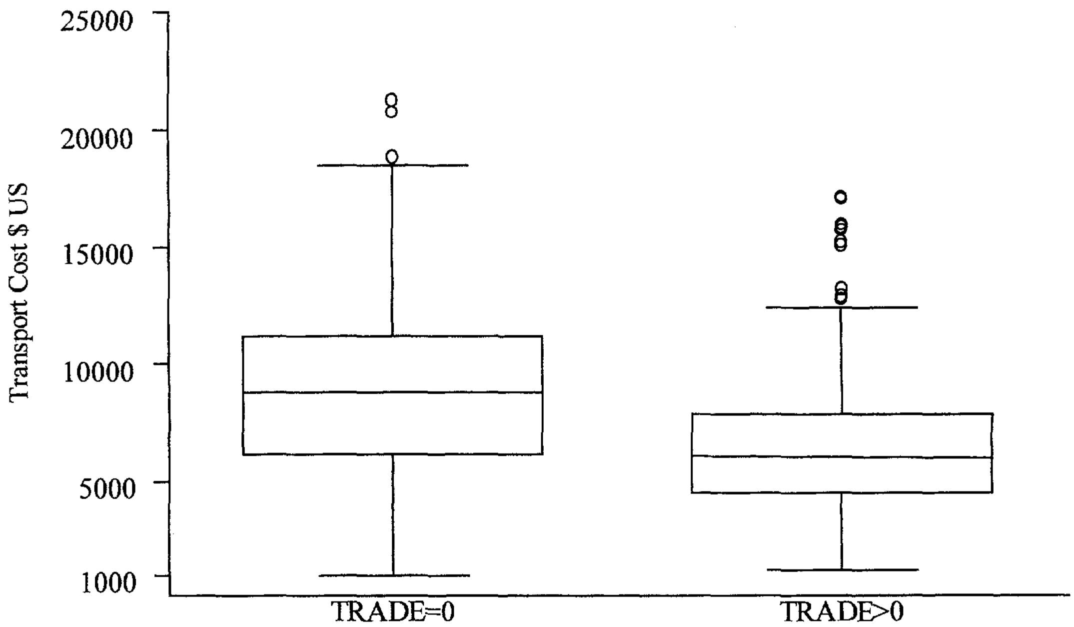
1 c. SSA and main export markets



Legend

USA: United States
JPN: Japan
DEU: Germany

Figure 2
Predicted Transport Cost for SSA actual and possible trade flows



Note: The lines in the box represent the 25th, 50th and 75th percentiles. The top extreme line indicates x[75th] + 1.5*(x[75 th]-x[25 th]) or the maximum if it is lower than that value. The bottom extreme line indicates x[25th] - 1.5*(x[75 th]-x[25 th]) or the minimum if it is higher than that value. Any observations outside these lines are represent individually by the dots.

Our predicted values of transport costs are generated for all bilateral pairs of countries in the sample, including some for which there is not actual trade flow reported. Comparing the trade costs of countries which trade with those which do not provides further insight into the importance of transport costs relative to other factors in determining intra-African trade volumes. This is done in figure 2. We can see that non-trading partners have average transport costs of $8,000, 50% higher than the average of trading partners; for more than three-quarters of non-trading partners transport costs exceed the mean for trading partners. This illustrates the obvious fact that transport costs are an important, but not the only factor behind the small trade volume among some African countries.[26]

Table V in the appendix reports some of the predicted transport costs that we have calculated. It gives transport costs from selected African destinations, expressed relative to the predicted cost of shipping from Baltimore to Germany. The columns correspond to the major World and African

[26] Non-reporting of trade data for intra-African trade is an important issue here. It is possible that some of the countries classified as having zero trade are in fact just not reporting data. If these countries have relatively low (high) transport costs then the true difference of transport costs would be higher (lower) than the one reported above.

markets, the rows correspond to African countries sorted by access to the sea and location. The largest numbers in the table are for shipping from landlocked countries on one side of the continent to landlocked countries on the other: shipping from Uganda to Chad, Mali or Niger has predicted transport costs more than four times higher than shipping from Baltimore to Germany.

The evidence that African trade faces an important obstacle in the form of higher transport costs is compelling. We now focus on SSA trade flows.

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. 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 gravity model, augmenting them with African dummies: African importer (*Africa*), exporter (p*Africa*), importer and exporter (*AA*), and an interaction of the latter with distance (*AAdistance*). Table 6 provides the estimates and investigates whether or not they survive inclusion of the infrastructure variables.

Starting with the first column of table 6 we find that African countries' bilateral imports and exports with a non African partner stand at respectively 71% (= exp(-0.34)) and 38% of the level of a non-SSA country pair. So the basic gravity specification (income and distance) cannot account for the poor performance of African trade even when augmented with geographical variables (border and island dummies). Column four adds the infrastructure measures. Including these halves the exporter disadvantage and leads to a change in sign of the importer dummy implying that poor infrastructure is a major determinant of the low bilateral trade values of African countries.

Turning to the issue of Intra-African trade, column two adds a dummy for both partners in SSA. It is positive and significant but it is not large enough to offset the African importer/exporter disadvantage. According to this specification a pair of SSA partner trades only 36% of the value traded by a non-SSA pair with similar characteristics. [27] This result is overturned with the inclusion of the infrastructure variables (column five), once these are accounted for a SSA pair trades 17% *more* than a non-SSA pair.

In column three we ask if distance is more important in reducing trade between a pair of African countries by including *AAdistance*. 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. Column three shows that Intra-African trade is indeed more responsive to distance, with an elasticity of –1.63 compared to –1.33 for a non-SSA pair.[28]

One way to summarize the results of table 6 is to calculate the critical distance above which an African pair trades less than a non-African pair. When infrastructure is not included, this is 90 km, below the minimum distance between any African pair. When infrastructure is included (last column) the critical distance increases to 4915 km, greater than three quarters of intra-African distances. More interestingly the majority of country pairs at distances higher than this value are on opposite coasts and thus the gravity results confirm the fact that Intra-African trade is concentrated at the sub-regional level with little East-West trade taking place.[29]

The main result from this section is that African countries do tend to trade less both with the ROW and with themselves than would be predicted by a simple gravity model, and the reason for that is their poor infrastructure. The impact of poor infrastructure on African trade levels may be even higher than estimated above as it is likely to have an indirect effect through lower income.

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[27] This is obtained from exp(-0.47-1.12+0.59).

[28] 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, there is no mention of this point in their work.

[29] See Yeats (1999) page 58 on this matter.

Table 6

Value of imports into country j from country i. (Tobit)

	1	2	3	4	5	6
ln*Distance*	-1.39*	-1.35*	-1.33*	-1.21*	-1.16*	-1.14*
	(-26.7)	(-25.0)	(-24.4)	(-23.3)	(-21.6)	(-21.0)
ln*Y*	1.38*	1.38*	1.38*	1.21*	1.22*	1.22*
	(65.1)	(65.2)	(65.2)	(51.5)	(51.6)	(51.6)
ln*pY*	1.58*	1.58*	1.58*	1.42*	1.42*	1.43*
	(74.6)	(74.7)	(74.8)	(60.3)	(60.5)	(60.5)
border	0.49**	0.44***	0.34	0.70*	0.65*	0.56**
	(1.99)	(1.81)	(1.36)	(2.86)	(2.68)	(2.23)
isldummy	0.55*	0.54*	0.54*	0.44*	0.42*	0.43*
	(5.45)	(5.31)	(5.32)	(4.36)	(4.22)	(4.24)
pisldummy	0.20**	0.19***	0.19***	0.13	0.12	0.12
	(1.98)	(1.83)	(1.84)	(1.34)	(1.19)	(1.21)
ln*Inf*				-1.28*	-1.29*	-1.30*
				(-11.8)	(-12.0)	(-12.0)
ln*pInf*				-1.29*	-1.30*	-1.31*
				(-11.9)	(-12.00)	(-12.1)
ln*(1+Inftran)*				-1.07*	-1.05*	-1.04*
				(-8.41)	(-8.29)	(-8.21)
ln*(1+pInftran)*				-0.75*	-0.74*	-0.73*
				(-5.87)	(-5.77)	(-5.68)
Africa	-0.34*	-0.47*	-0.48*	0.23**	0.07	0.07
	(-3.24)	(-4.14)	(-4.16)	(2.08)	(0.64)	(0.61)
pAfrica	-0.98*	-1.12*	-1.12*	-0.45*	-0.61*	-0.61*
	(-9.25)	(-9.65)	(-9.67)	(-4.10)	(-5.15)	(-5.18)
AA		0.59*	2.96**		0.70*	3.09**
		(2.95)	(2.06)		(3.56)	(2.22)
AAdistance			-0.30***			-0.30***
			(-1.66)			(-1.74)
N	8556	8556	8556	8556	8556	8556
Pseudo R^2	0.22	0.22	0.22	0.23	0.23	0.23
σ	3.16	3.16	3.16	3.07	3.07	3.07

Notes:

1) ***, **,* indicates significance at 10%, 5% and 1% respectively. t-statistics in parenthesis
2) Constant included in all specifications but not reported.
3) Pseudo $R^2=1-L_1/L_0$ Where L_1 is the log likelihood value of the model when all the regressors are included whereas L_0 corresponds to the likelihood when only a constant is included. This is not directly comparable to the OLS R^2. σ gives the standard error of the Tobit estimate, see Appendix III for details.
4) *Africa*=1 if importer is in SSA, *pArica*=1 if exporter is in SSA, *AA*=1 if both partners are in SSA, *AAdistance*=*AA***distance*$_{ij}$ the variables are zero otherwise.

6. Conclusion

Transport costs 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 in terms of geography and a measure of the infrastructure of the trading countries, and of any countries through which their trade passes.

Our approaches are able to explain a high proportion of the cross country variation in transport costs. Using one of our data sets we are able to show how land distance is much more costly than sea distance. From both data sets, we see that landlocked countries are disadvantaged, although they are able to overcome a substantial proportion of their disadvantage if their infrastructure, and the infrastructure of their transit countries, is of high standard.

Analysis of bilateral trade data provides a strong check on the importance of our infrastructure variables, producing results consistent with the direct estimation of transport costs. It also enables us to produce an estimate of the elasticity of trade flows with respect to transport costs, which we find to be approximately – 2.5. This is a large number, and means that halving transport costs increases the volume of trade by a factor of five, or improving infrastructure from the 75^{th} percentile to the 50^{th} increases the volume of trade by 50%.

Finally, we turn to looking at intra-African trade flows. These are somewhat lower than would be predicted by standard gravity modeling, and we show that most of this poor performance can be explained by our infrastructure variables.

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Appendix

Table I

Variable	Description	Source	Use
Distance	Great circle distance between trading partners (1000's km unless ln is used)	Fitzpatrick (1986), author's calculations	All
Distsea	Sea distance around continents from Baltimore to the sea port of landfall (1000's km)	DMA (1985), author's calculations	Shipping
Distland	Great circle land distance from sea port of landfall to capital of destination (1000's km)	Author's 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, author's calculations	All
Inftran	Average value of infrastructure for the transit countries if a country is landlocked, zero otherwise.	Canning 1998, UNCTAD, author's 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
T_{ship}	Cost of shipping a 40' container from Baltimore (1000's US $, 1999)	Panalpina	Shipping
t_{cif}	Ratio of transport costs to free on board value for aggregate imports of a country (i.e. cif/fob – 1)	IFS 1995, 1990 series	Cif/fob
Y	GDP in current $US market prices	WDI 1998	Gravity
Imports	Aggregate imports data SITC rev.2, 1000's current US$. For some countries with missing data the reported exports from the partner were used as imports.	Commtrade	Gravity

Notes: In the text ln*variable*: stands for the natural logarithm of *variable,* p*variable*: stands for the trade partner's *variable and* w*variable*[30]: stands for the import share weighted sum of *variable*

[30] E.g.: $wx_j = \sum_i \frac{M_{ij}}{M_j} x_{ij}$, where M_{ij} is CIF imports of j from i.

Table II

List of countries in different samples

Shipping	*Cif/fob*	*Gravity*
Argentina	Algeria	Argentina
Armenia*	Argentina	Australia
Austria	Australia	Austria
Azerbaijan*	Austria	Bangladesh
Belerus*	Bangladesh	Belgium
Belgium	Belgium	Benin
Benin	Benin	Bolivia
Bhutan	Bolivia	Botswana
Bolivia	Brazil	Brazil
Botswana	Burkina Faso	Bulgaria
Brasil	Burundi	Burkina Faso
Burkina Faso	Cameroon	Burundi
Burundi	Canada	Cameroon
Cameroon	Central African Rep.	Canada
Central African Rep.	Chad	Central African Rep.
Chad	Chile	Chad
Chile	China	Chile
China	Colombia	China
Congo	Zaire	Colombia
Czech Republic*	Congo,Rep	Costa Rica
Eritrea*	Costa Rica	Cote d'Ivoire
Ethiopia*	Cote d'Ivoire	Denmark
Georgia*	Denmark	Dominican Republic
Germany	Dominican Republic	Ecuador
Ghana	Ecuador	Egypt, Arab Rep
Hungary	Egypt, Arab Rep	El Salvador
India	El Salvador	Ethiopia
Italy	Finland	Finland
Cote d'Ivoire	France	France
Kazakhstan*	Gabon	Gambia,The
Kenya	Gambia,The	Germany
Kyrgyzstan*	Germany	Ghana
Lesotho	Ghana	Greece
Luxembourg*	Greece	Guatemala
Macedonia*	Guatemala	Guinea
Malawi	Haiti	Guinea-Bissau
Mali	Honduras	Haiti
Moldova*	Hong Kong,China	Honduras

Shipping	*Cif/fob*	*Gravity*
Mozambique	India	Hong Kong,China
Nepal	Indonesia	Hungary
Netherlands	Iran, Islamic Rep	India
Niger	Ireland	Indonesia
Nigeria	Israel	Ireland
Paraguay	Italy	Israel
Peru	Jamaica	Italy
Russia*	Japan	Jamaica
Rwanda	Jordan	Japan
Senegal	Kenya	Jordan
Slovakia*	Korea, Rep	Kenya
South Africa	Madagascar	Korea, Rep
Swaziland	Malawi	Laos PDR
Switzerland	Malaysia	Lesotho
Taijikstan*	Mali	Madagascar
Tanzania	Mauritania	Malawi
Thailand	Mauritius	Malaysia
Togo	Mexico	Mali
Turkey	Mozambique	Mauritania
Turkmenistan*	Nepal	Mauritius
Uganda	Netherlands	Mexico
Uruguay	New Zealand	Mongolia
Uzbekistan*	Nicaragua	Morocco
Zambia	Niger	Mozambique
Zimbabwe	Nigeria	Namibia
	Norway	Nepal
	Oman	Netherlands
	Pakistan	New Zealand
	Panama	Nicaragua
	Papua New Guinea	Niger
	Paraguay	Norway
	Peru	Pakistan
	Philippines	Panama
	Poland	Papua New Guinea
	Portugal	Paraguay
	Romania	Peru
	Rwanda	Philippines
	Saudi Arabia	Poland
	Senegal	Portugal
	SierraLeone	Romania
	Singapore	Rwanda
	South Africa	Senegal
	Spain	SierraLeone
	SriLanka	Singapore
	Sweden	Spain

Shipping	*Cif/fob*	*Gravity*
	Switzerland	SriLanka
	Syrian Arab Republic	Sweden
	Thailand	Switzerland
	Togo	Syrian Arab Republic
	Trinidad and Tobago	Tanzania
	Tunisia	Thailand
	Turkey	Togo
	Uganda	Tunisia
	United Arab Emirates	Turkey
	United Kingdom	Uganda
	United States	United Kingdom
	Uruguay	Uruguay
	Venezuela	Yemen, Rep
	Zambia	South Africa
	Zimbabwe	Zaire
		Zambia
		Zimbabwe

* Excluded from the specifications in columns 3 and 4 of Table I in the text due to missing data for infrastructure.

Table III

Landlocked country	*Transit country*
Austria	Germany
	Italy
Burundi	Kenya
	Tanzania
	Uganda
Burkina Faso	Cote d'Ivoire
	Togo
Bolivia	Argentina
	Brazil
	Chile
	Peru
Botswana	South Africa
Central African Republic	Cameroon
	Congo, Rep.
	Congo, Dem. Rep.
Switzerland	Germany
	Italy
	Netherlands
Czech Republic	Austria
	Germany
	Italy
Hungary	Austria
	Italy
Laos PDR	Thailand
	Vietnam
Lesotho	South Africa
Mali	Burkina Faso
	Cote d'Ivoire
	Senegal
Mongolia	China
Malawi	Botswana
	Mozambique
	Zambia
	Zimbabwe
Niger	Benin
	Burkina Faso
	Nigeria
	Togo
Nepal	Bangladesh
	India
Paraguay	Argentina
	Brazil
	Chile
	Uruguay
Rwanda	Burundi
	Kenya
	Tanzania
	Uganda
Chad	Cameroon
	Nigeria
Uganda	Kenya
	Tanzania
Zambia	Mozambique
	Tanzania
	South Africa
Zimbabwe	Mozambique
	Tanzania
	South Africa

Construction of variables:

Own Infrastructure: Each country's infrastructure is measured by an index constructed from four variables; km 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 took the mean 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 variables 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 CRS to the private inputs than our assumption is that $\chi = 0.3$. This value implies that the transport cost per km of the worse infrastructure is approximately ten times that of the best one. (Since most of the specifications used are log-linear this transformation is usually irrelevant).

Transit infrastructure: Let L denote a given landlocked country and L_t the set of transit countries L uses to reach the sea. Ideally we would use a set of weights that reflect the probability that the infrastructure of each country in L_t is used by L. However, the available data reports solely if a country is used for transit or not, so an equal probability of infrastructure use was assigned to each transit country in L_t. So, if country L uses n transit countries the variable inftran gives an equal weight of 1/n to each of those countries' measure of the infrastructure index described above.

Three 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, landlocked transport cost to neighbors should not include the cost of going through transit infrastructure and thus when necessary our variable is adjusted to reflect this fact.

Table IV: Summary statistics:

Shipping: All data is for 1998 (n=64)

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

Restricted sample (countries for which infrastructure data is available, n=47)

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

CIF/FOB: All data for 1990 (n=98)

Variable	Mean	Standard deviation
ln*t*	-2.325	0.666
ln*inf*	0.289	0.458
lninftran	0.139	0.322
wln*distance*	1.034	0.651
wln*pinf*	-0.112	0.092
wln*pinftran*	0.021	0.021
ldldummy	0.163	0.372
wbor	0.141	0.177
isldummy	0.153	0.362
wisldummy	0.177	0.116

Gravity (***Tobit***): All data for 1990 (n=8556).

Variable	Mean	Standard deviation
ln *Distance*	8.764	0.790
ln*Y*	23.772	2.206
ln*pY*	23.772	2.206
ln*Inf*	0.283	0.470
ln*pInf*	0.283	0.470
ln*(1+Inftran)*	0.155	0.330
ln*(1+pInftran)*	0.155	0.330
isldummy	0.151	0.358
pisldummy	0.151	0.358
border	0.027	0.161

Table V

Predicted transport costs from SSA to selected destinations

	From/To	*US*	*Germany*	*Japan*	*South Africa*	*Kenya*	*Zaire*	*Nigeria*	*Uganda*
	United States	-	1.00	1.03	1.65	1.91	1.98	1.69	2.63
	South Africa	1.67	1.25	1.24	-	1.16	1.25	1.41	1.64
Coastal									
Low/Middle income East and Southern Africa	*Zaire*	2.08	1.47	1.67	1.30	1.47	-	1.32	1.05
	Kenya	1.98	1.34	1.40	1.19	-	1.45	1.61	0.54
	Madagascar	2.50	1.79	1.66	1.24	1.52	2.07	2.23	2.27
	Mozambique	2.63	1.95	1.90	0.55	1.78	2.03	2.26	2.55
	Mauritius	1.54	1.11	0.97	0.87	1.04	1.38	1.44	1.54
	Mean	**2.15**	**1.53**	**1.52**	**1.03**	**1.45**	**1.73**	**1.77**	**1.59**
Low Income Western Africa	*Benin*	1.79	1.25	1.57	1.48	1.66	1.35	0.31	2.21
	Gambia, The	1.43	1.10	1.43	1.55	1.80	1.67	1.23	2.43
	Ghana	1.73	1.23	1.54	1.46	1.67	1.37	0.65	2.22
	Guinea	1.69	1.29	1.65	1.71	2.00	1.81	1.30	2.71
	Guinea-Bissau	1.68	1.29	1.67	1.78	2.07	1.90	1.39	2.79
	Mauritania	1.94	1.44	1.94	2.18	2.49	2.34	1.74	3.36
	Sierra Leone	1.66	1.27	1.61	1.66	1.94	1.75	1.25	2.62
	Togo	1.63	1.15	1.44	1.37	1.54	1.26	0.50	2.05
	Mean	**1.69**	**1.25**	**1.61**	**1.65**	**1.90**	**1.68**	**1.04**	**2.55**
Middle Income Western Africa	*Cameroon*	1.83	1.25	1.51	1.35	1.44	1.03	0.73	1.86
	Cote d'Ivoire	1.72	1.25	1.57	1.51	1.75	1.48	0.88	2.34
	Senegal	1.53	1.17	1.54	1.69	1.95	1.83	1.36	2.65
	Mean	**1.69**	**1.23**	**1.54**	**1.52**	**1.71**	**1.44**	**0.99**	**2.28**
*Oil producers**	*Angola*	2.08	1.51	1.69	1.23	1.54	0.69	1.38	2.03
	Congo, Rep.	2.14	1.51	1.72	1.34	1.51	0.10	1.36	1.95
	Gabon	1.87	1.31	1.57	1.34	1.50	0.97	0.95	1.96
	Nigeria	1.76	1.23	1.54	1.45	1.62	1.30	-	2.14
	Mean	**1.96**	**1.39**	**1.63**	**1.34**	**1.54**	**0.76**	**1.23**	**2.02**
	Mean Coastal	**1.86**	**1.35**	**1.58**	**1.41**	**1.70**	**1.46**	**1.26**	**2.16**
Landlocked									
Low/Middle income East and Southern Africa	*Burundi*	2.57	1.76	1.90	1.48	1.14	0.96	1.95	1.32
	Malawi	2.58	1.84	1.86	1.14	1.37	1.81	2.12	1.99
	Rwanda	1.83	1.24	1.35	1.08	0.77	0.69	1.39	0.34
	Uganda	2.58	1.74	1.87	1.58	0.53	1.03	2.02	-
	Zambia	2.78	2.00	2.06	1.13	1.63	1.14	2.21	2.28
	Zimbabwe	2.35	1.70	1.72	0.54	1.40	1.64	1.93	2.00
	Mean	**2.45**	**1.72**	**1.79**	**1.16**	**1.14**	**1.21**	**1.94**	**1.59**
Low Income Western Africa	*Burkina Faso*	2.55	1.75	2.31	2.35	2.61	2.30	1.34	3.49
	Central African Rep.	3.13	2.10	2.48	2.19	2.12	1.05	1.97	2.66
	Chad	3.96	2.54	3.22	3.16	3.13	2.87	1.43	4.05
	Mali	2.91	2.09	2.74	2.86	3.26	2.94	1.95	4.38
	Niger	3.20	2.14	2.83	2.89	3.14	2.78	0.95	4.17
	Mean	**3.15**	**2.13**	**2.72**	**2.69**	**2.85**	**2.39**	**1.53**	**3.75**
	Mean landlocked	**2.77**	**1.90**	**2.21**	**1.86**	**1.92**	**1.75**	**1.75**	**2.67**

Notes: 1) The country classification is the one used by the World Bank

2) The choice of African countries in the columns reflects the largest markets in each of the SSA regions and a landlocked country, Uganda.

3) * Transport costs for petroleum products are typically higher than for other products thus it is likely that these values underestimate the true transport cost for the oil producers' exports but they are indicative of their import costs.

Figure I

Relative Transport Cost of Landlocked countries predicted by cif/fob and shipping data

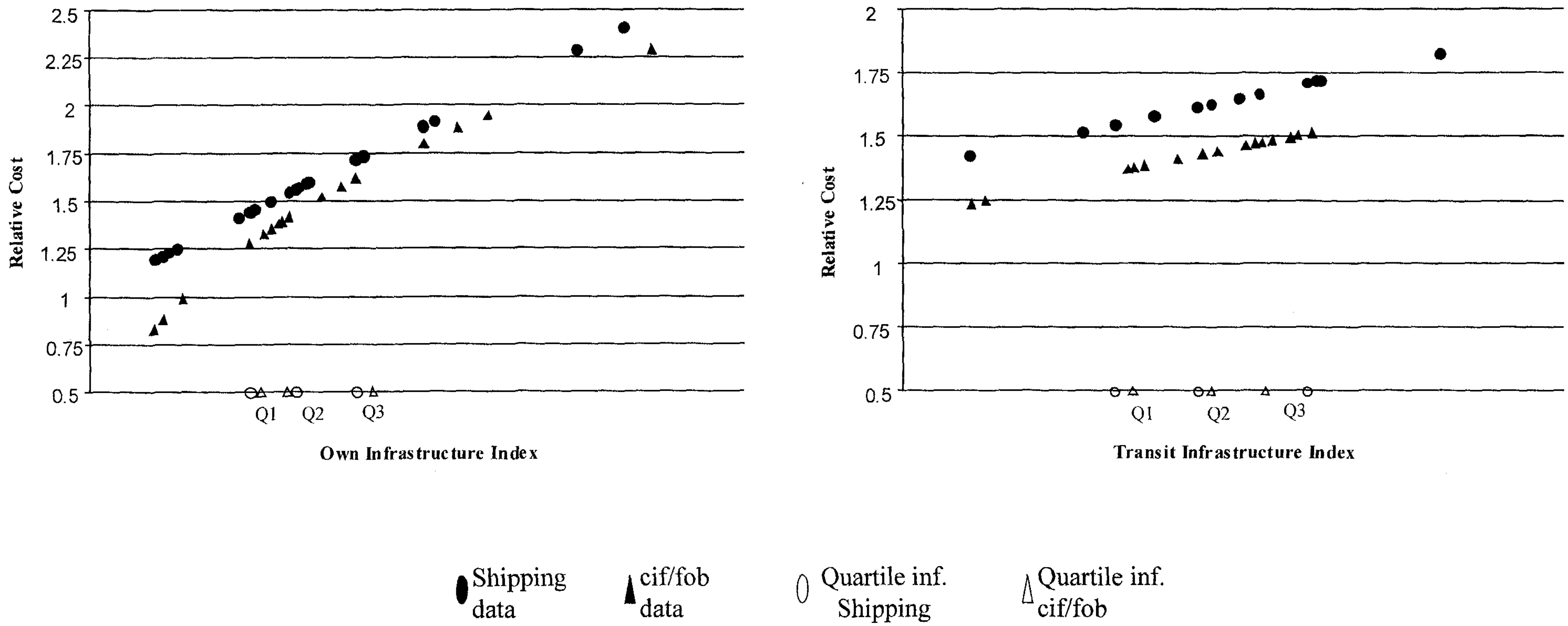
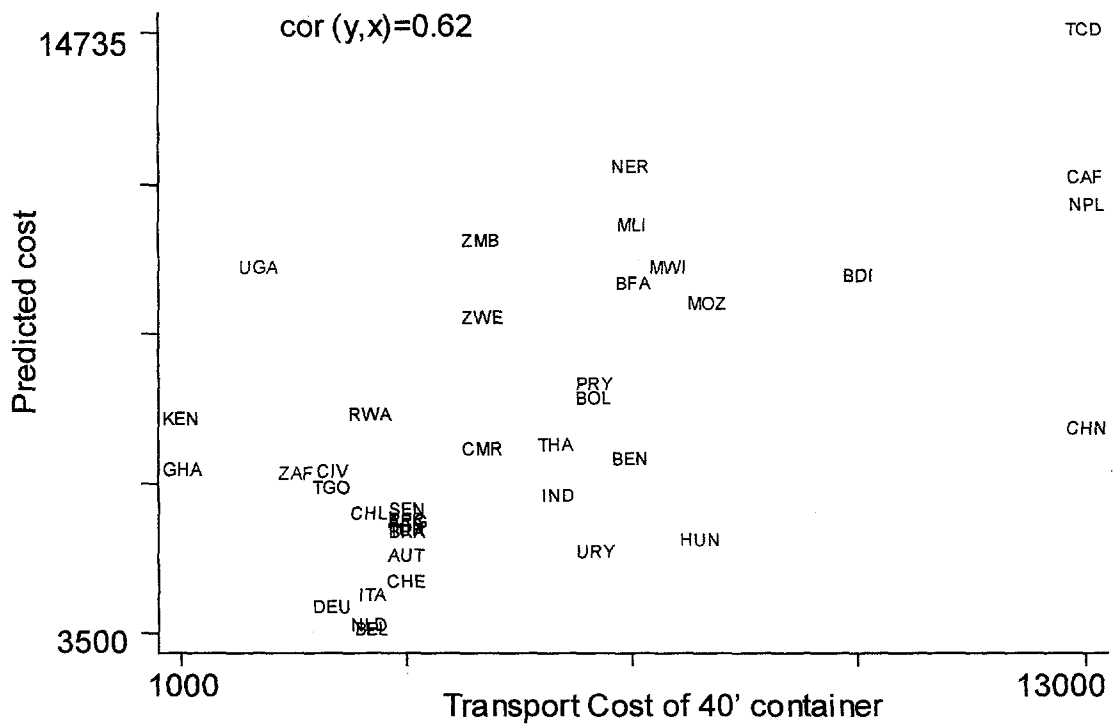


Figure II

Predicted transport cost $US of 40' container vs. actual data



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