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Infrastructure, Transport Costs and Trade: A New Approach

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Abstract:
This paper investigates the impact of the quality of infrastructure on exports, with a specific focus on Sub-Sahara Africa. Improving the quality of infrastructure has a positive effect on exports by lowering the transport costs faced by the exporter. This paper provides a new specification on how to model transport costs in the gravity model. Specifically, minimum and maximum infrastructure variables are included in the model rather than exporter and importer infrastructure variables. The gravity model forms part of a Heckman selection model, which is used to deal with the biases induced by excluding zero bilateral exports in the gravity model. The results suggest that it is the minimum quality of infrastructure between two trading countries that matters most for transport costs and therefore trade. This result also holds when using disaggregated export data and specific infrastructure variables. No robust evidence was found that Sub-Sahara Africa exports less than expected or that improving the quality of infrastructure has a significantly different effect on Sub-Saharan exports. However, using disaggregated trade data it was found that Sub-Saharan countries, given its characteristics, export more primary products and less manufactured goods (although the findings for manufactured goods are not robust).

1) Introduction

Transport costs represent a significant barrier to international trade. It imposes additional charges that the exporter or importer (depending on the elasticities of supply and demand) must absorb in order to penetrate foreign markets (Amadji and Yeats, 1995). High transport costs therefore isolate countries by inhibiting their ability to participate in the global economy. In Sub-Saharan Africa (hereafter Africa) transport costs are particularly problematic. The average cost to export a standard container from Africa was $1649, nearly double the OECD average of $889 (Doing Business Report, 2007). According to Amadji and Yeats (1995) the relatively low level of African exports is essentially due to the high transport costs in the region. Transport costs, in turn, depend on the quantity and quality of transport infrastructure. Limao and Venables (2001) found that low levels of infrastructure accounted for 40 percent of predicted transport costs for coastal countries and up to 60 percent for landlocked countries. Thus investing in infrastructure is likely to have a significant effect on trade via altering transport costs.

This paper will examine the links between the quality of transport infrastructure, transport costs and trade, with a particular focus on Africa. The main objective is to establish how country infrastructures interact to determine transport costs. This paper argues that it is the minimum quality of infrastructure between two trading countries that matters most for transport costs. For example, exports from South Africa to the US are likely to be constrained by the quality of South African infrastructure which raises transport costs on the South African side; however exports from South Africa to Mozambique are likely to be constrained by the low quality infrastructure in Mozambique.

In order to determine the interaction between country infrastructures a gravity model is used. The gravity model is regularly used to estimate the impact of trade agreements, currency unions, common languages and infrastructure on trade. This paper builds on previous gravity model literature and contributes to these papers in several ways:

Firstly, the gravity model (as derived by Anderson and van Wincoop (2003)) is used as the outcome equation in a Heckman selection model. The Heckman selection model is used to take into account the process that lead to zero bilateral exports. The standard log linear form of the gravity model loses important information by excluding zero bilateral trade flows; this represents a non-random screening that leads to biased or inconsistent estimates (Coe and Hoffmaister, 2007). In contrast the Heckman selection model uses the information from the non-trading countries to improve the estimates of the parameters in the gravity model.

Secondly, this paper includes minimum and maximum bilateral infrastructure variables in the gravity model. This is done in order to test how country infrastructures interact to determine transport costs. Including only importer and exporter infrastructure variables do not adequately capture the interaction of the trading partners' infrastructure. A dummy variable - which takes on the value of 1 if both the exporter and importer have above average infrastructure and 0 otherwise - is also included in the gravity model to test whether there are any threshold effects in determining transport costs.

Thirdly, this paper takes into account the heterogeneity of the exported goods by using disaggregated data in the form of manufactured and primary product exports. The impact of transport costs are likely to differ depending on the characteristics of the goods exported, thus manufactured and primary product exports (along with total exports) are used as dependent variables in the gravity model. The heterogeneity of transport infrastructure is also taken into account. Specific infrastructure indicators (port, air transport, rail and telecommunications) are used as alternatives to the overall quality indices.

Lastly, an African dummy variable is included in all the gravity regressions in order to test whether African countries trade less (or more) than non-African countries. Interaction variables for African infrastructure are also included in order to test whether the quality of infrastructure has a different impact on African exports.

The rest of the paper has the following structure: Section 2 provides a literature review which is supported with some recent trade data. Section 3 presents a theoretical background of the gravity model. Section 4 and 5 addresses the estimation and data respectively. Section 6 provides the results from the gravity model and Section 7 tests the sensitivity of these results. Section 8 simulates the effect of improved quality of infrastructure on exports in the SADC region and Section 9 concludes and summarises the main findings of this paper.

2) African exports: Examining the literature and the facts

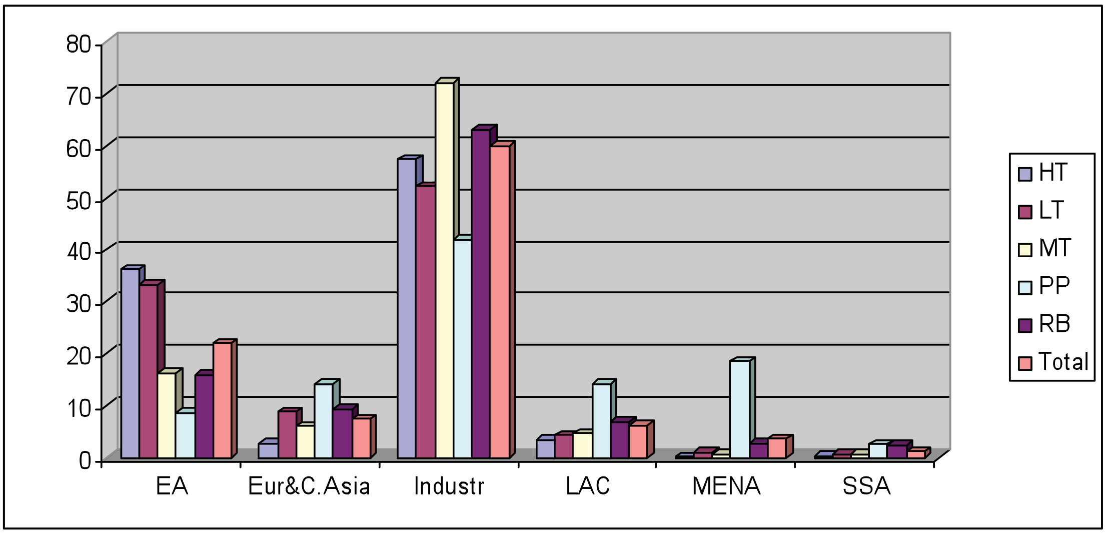
"….The last three decades have seen stagnation in Africa. The composition of Africa's exports has essentially remained unchanged, and has contributed to a collapse in Africa's share of world trade…Africa will not be able to achieve the Millennium Development Goals, nor set itself on a sustainable path to growth and poverty reduction, without increased trade." (Commission for Africa, 2005:256).

2.1) Export performance

Africa's importance in global trade has declined over the past 50 years. Africa's share in total exports in 2005 was only 1.09 percent which is substantially less than the approximately 3.1 percent of global exports in 1955 (Amadji and Yeats, 1995). Figure 1 highlights the extent to which Africa has become marginalised in world trade. Africa's share in primary product exports was only 2.55 percent in 2005, despite the bulk of African exports consisting of primary products. Export shares of low, medium and high technology goods were negligible.

Results like Figure 1 have led several authors to claim that Africa trades 'too little' (see Mansoor, 1989, and Kourouma, 1989). Coe and Hoffmaister (1998) argued that this was not the case. They addressed bilateral trade between Africa and industrialised countries from 1970 to 1995 and found no evidence that it was unusually low. Using a non linear gravity model on a large sample of countries (84 developing countries and 22 industrialised countries) Coe and Hoffmaister (1998) concluded that African trade is explained by the standard determinants of bilateral trade such as economic size and geographical distance. Furthermore, once all Africa's characteristics were taken into account African trade was not unusually low, in fact it was found to be slightly higher than expected.

Figure 1: Share of Global Exports by region, 2005



Source: UN Comtrade, Author's Calculation
Note: Exports Classified according to the Lall Classification (Lall, 2000). The Lall Classification is a useful way of categorising trade as it categorises goods as either manufactures or primary products (PP). Furthermore the manufactures category is divided up into high (HT), medium (MT) and low technology (LT) manufactures and resource based manufactures (RB).
The regions included are East Asia (EA), Europe and Central Asia (Eur&C.Asia), Industrialised (Industr), Latin America and the Caribbean (LAC), Middle East and North Africa (MENA) and Sub Saharan Africa (SSA).

Rodrik (1998) also found that Africa does not trade less than expected. He regressed trade shares of GDP on several determinants using cross-sectional, pooled cross-sectional and time series techniques and data from 1964 to 1994. He concluded that the African region participates in international trade as much as would be expected given its characteristics. Furthermore, he argued that the marginalisation of African countries in world trade was entirely due to the slow growth of African economies. However, this argument oversimplifies the relationship between exports and growth as the causality is likely to run both ways. Rodrik (1998) concluded that trade and trade policy works the same in Africa as it does elsewhere in the world. This is an important result as it means that studies of countries which have managed to successfully escape the poverty trap could potentially be applied to African countries. Johnson *et al* (2007) did just that, they used countries which had weak institutions in the 1960s and still managed to grow as benchmarks to evaluate potential constraints on sustained growth in Africa. They concluded that it is possible for African countries to overcome their inherited institutional weaknesses. They found that escapes from poverty have generally included an export focus – in most cases manufactured exports.

2.2) Identifying export constraints: Transport costs

In order to boost African exports the current major constraints need to be identified. Many constraints have been highlighted; for example anti-export policies (Collier and Gunning, 1999), uncompetitive real exchange rates (Elbadawi, 1999) and other government policies such as restrictive customs regulation and poor customs administration (Clarke *et al*, 2004). Amadji and Yeats (1995) investigated whether transport costs contributed to the marginalisation of African exports. They used cost-insurance-freight (c.i.f.) and free-alongside-ship (f.a.s.) data of African exports to the US in order to calculate *ad valorem* transport costs. This was compared to the average tariffs levied and to *ad valorem* transport costs of other developing countries. It was found that African transport costs were on average 20 percent higher than other developing nations. These results were only for trade with the US and are thus not conclusive proof of high transport costs in Africa, although it is certainly a good indication. Transport costs were found to be significantly higher than the average tariffs levied on these goods by importing countries. In fact, due to a number of agreements African countries tend to receive trade preferences in OECD countries and face relatively little tariffs. This led them to conclude that foreign trade policies have not played an important role in the decline of export shares for Africa. They also found that transport costs had an adverse affect on the composition of the exported goods as transport costs were higher for processed commodities than for unprocessed commodities. This inhibited diversification into processed products in many countries. Thus not only did transport costs have a significant impact on African exports, it also determined what was exported.

More than a decade since Amadji and Yeats (1995) wrote their paper there is evidence that transport costs remain a significant problem. The Doing Business Report (World Bank, 2007) provides an indication of the extent of the problem in the Trading Across Borders section (see Table 1). The cost to import and export a container to and from Africa is considerably higher than for any other region. The average cost to export a standard container from Africa was $1649, nearly double the OECD average of $889. Furthermore it takes on average 37 days to export goods from an African country. This is 15 days more than the Latin America and Caribbean average and four times the OECD average.

Amadji and Yeats (1995) argued that the anti-competitive domestic transport policies undertaken by African governments have had an important negative influence on transport costs. They therefore argued for the deregulation of the transport sector. Although this corrective action will help decrease transport costs, they did not address one of the biggest determinant of transport costs – infrastructure. Infrastructure directly affects transport costs by determining the type of transport used (for example, the size of the road determines the maximum size of the truck) and delivery time for the goods (Djankov *et al,* 2006). Infrastructure therefore has a direct effect on freight charges. Other direct transport costs include insurance, which is likely to be higher if infrastructure is poor. Indirect effects of poor infrastructure include holding costs for goods in transit and inventory costs in order to safeguard production against the variability of delivery dates of imported inputs.

Table 1: Transport costs and time delays in Africa, 2007

Economy	Ease of Doing Business Rank	Trading Across Borders				
		Rank	Time for export (days)	Cost to export (US$ per container)	Time for import (days)	Cost to import (US$ per container)
East Asia	**76.71**	**74.52**	**25.52**	**891.96**	**27.83**	**1035.91**
Latin America and Caribbean	**83.39**	**84.07**	**22.43**	**1085.97**	**27.87**	**1249.53**
OECD	**21.79**	**23.43**	**10.00**	**889.78**	**10.70**	**987.48**
Sub Sahara Africa	**135.13**	**129.49**	**37.13**	**1649.76**	**46.56**	**1979.80**
Benin	147.00	120.00	34.00	1167.00	41.00	1202.00
Botswana	49.00	144.00	33.00	2328.00	43.00	2595.00
Burundi	175.00	164.00	47.00	2147.00	71.00	3705.00
Cameroon	154.00	124.00	27.00	907.00	33.00	1529.00
Cape Verde	128.00	47.00	21.00	1024.00	21.00	1024.00
Central African Rep.	174.00	171.00	57.00	4581.00	66.00	4534.00
Côte d'Ivoire	157.00	146.00	23.00	1653.00	43.00	2457.00
Gabon	141.00	99.00	19.00	1510.00	35.00	1600.00
Gambia	127.00	65.00	23.00	889.00	23.00	949.00
Ghana	109.00	74.00	21.00	822.00	42.00	842.00
Lesotho	119.00	125.00	44.00	1188.00	49.00	1210.00
Madagascar	160.00	143.00	48.00	982.00	48.00	1282.00
Malawi	118.00	159.00	45.00	1623.00	54.00	2500.00
Mauritania	159.00	151.00	35.00	1360.00	42.00	1363.00
Mauritius	30.00	16.00	16.00	683.00	16.00	683.00
Mozambique	140.00	137.00	27.00	1155.00	38.00	1185.00
Namibia	36.00	140.00	29.00	1539.00	24.00	1550.00
Niger	171.00	160.00	59.00	2945.00	68.00	2946.00
Sierra Leone	155.00	123.00	31.00	1282.00	34.00	1242.00
South Africa	37.00	130.00	30.00	1087.00	35.00	1195.00
Sudan	148.00	174.00	56.00	1870.00	83.00	1970.00
Swaziland	91.00	145.00	21.00	1798.00	34.00	1820.00
Togo	149.00	60.00	24.00	872.00	29.00	894.00
Uganda	116.00	162.00	42.00	1050.00	67.00	2945.00
Zambia	103.00	158.00	53.00	2098.00	64.00	2840.00
Zimbabwe	144.00	166.00	52.00	1879.00	67.00	2420.00

Source: World Bank Ease of Doing Business Report (2007)
Note: Country rank out of 178 countries

2.3) What determines transport costs?

Limao and Venables (2001) studied the determinants of transport cost and found that they depend on a country's geography and on its level of infrastructure. They used two different sets of data to arrive at this conclusion. Firstly, they obtained quotes for shipping a standard container from Maryland, Baltimore (United States) to several destinations in 1990. Using a linear regression they found that for coastal countries domestic infrastructure explained 40 percent of the predicted transport costs, whilst for inland countries own infrastructure explain 36 percent and transit infrastructure (of bordering coastal countries) explained 24 percent. Secondly, Limao and Venables (2001) used c.i.f. and f.o.b. (free on board) data from the IMF DOTS database to calculate *ad valorem* transport costs. They used the *ad valorem* transport costs as the dependent variable in a Tobit regression. Once again infrastructure was found to be a highly significant determinant of transport costs. Improving a country's infrastructure from the median to the top 25^{th} percentile is equivalent to it being 2358 km closer to all its trading partners.

Limao and Venables (2001) also tested the impact of infrastructure on trade; if infrastructure has a significant impact on transport costs, then it should also be important in determining trade flows. Once again they found significant results: Moving from the median to the top 25^{th} percentile in the distribution of infrastructure raised trade volumes by 68 percent. Moving from the median to the 75^{th} percentile decreased trade volumes by 28 percent. Increasing the level of infrastructure above the median distribution therefore has significantly greater impact than falling below the median. This could indicate the existence of some sort of threshold for the level of infrastructure, or it could simply be due to the shape of the distribution of infrastructure. Unfortunately this is an interesting finding that Limao and Venables (2001) did not explore further.

Limao and Venables (2001) next turned their attention to intra-Africa trade. They found that a basic gravity specification could not account for Africa's poor intra-trade performance as the African dummy variable was significant and negative. However, once the infrastructure variables were included in the regression the African dummy variable switched signs, indicating that given its low level of infrastructure Africa actually trades *more* than expected. The severity of Africa's poor infrastructure is highlighted by the Africa Competitiveness Report (2007). One of the largest performance gaps highlighted by the report is infrastructure. Africa has the lowest regional infrastructure average out of all the regions. Five of the 10 countries with the worst infrastructure quality are in Africa. With the exception of the SACU countries, African countries infrastructure is ranked lowest out of all countries in the survey (see Table 2).

2.4) Impact of infrastructure on trade

Nordas and Piermartini (2004) built on the work done by Limao and Venables (2001) using trade and infrastructure data from 2000. Firstly, they argued against using direct transport costs such as the c.i.f/f.o.b ratio used by Limao and Venables (2001) as these ratios are not available for Europe or Japan, nor is it available at the disaggregate level. Furthermore the quality of c.i.f/f.o.b data is generally poor.

Secondly, they attempted to correct for an omitted variable bias in the Limao and Venables (2001) gravity model by using a theoretical gravity model as specified by Anderson and van Wincoop (2003). This was done by including multilateral resistance variables into the gravity model. These variables are supposed to capture the trade barriers between two trading countries relative to the average barriers of these two countries with all other trading partners (Anderson and van Wincoop, 2003). Nordas and Piermartini (2004) used the average weighted tariffs faced by the exporter and the average tariff of the importer as multilateral resistance variables. This is incorrect as using tariff variables will still result in an omitted variable bias since the tariff variables will not capture any of the other trade barriers faced by the trading countries.

Table 2: Comparing Africa's infrastructure, 2007

	Basic Requirements		Institutions		Infrastructure		Macroeconomy	
Country	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**
Latin America and Caribbean		4.41		3.69		3.25		4.2
East Asia		4.53		4.08		3.12		4.61
North Africa		4.67		4.13		3.53		4.57
Sub Sahara Africa		3.55		3.65		2.45		4
Benin	16	3.74	87	3.57	117	2	95	4.04
Botswana	82	4.3	38	4.53	67	3.38	43	4.85
Burundi	127	2.73	115	3.2	126	1.71	125	2.51
Cameroon	108	3.71	120	3.11	124	1.93	42	4.83
Gambia	105	3.84	57	4.11	97	2.62	108	3.77
Lesotho	107	3.72	89	3.56	121	2	54	4.64
Madagascar	114	3.6	98	3.43	119	2.03	118	3.39
Malawi	119	3.3	66	3.94	118	2.06	127	2.31
Mauritania	117	3.41	72	3.83	114	2.1	123	2.82
Mauritius	50	4.74	42	4.4	42	4.21	107	3.79
Mozambique	112	3.25	112	3.25	102	2.41	115	3.5
Namibia	72	4.44	49	4.23	45	4.16	45	4.79
South Africa	57	4.66	31	4.79	50	4.04	48	4.74
Uganda	121	3.27	103	3.38	122	1.99	69	4.42
Zambia	116	3.52	56	4.11	90	2.75	122	3.07
Zimbabwe	125	3.09	101	3.39	101	2.44	128	2.2

Source: World Economic Forum, Africa Global Competitiveness Report, 2007
Note: Country rank out of 128 countries
Score is calculated from the response to the survey question: "… in your country is (1=underdeveloped, 7=as developed as the world's best)

Thirdly, they constructed separate indices for each type of infrastructure (rail, roads, telecommunications, ports, airports and time for customs clearance) in order to test individual effects of the different forms of infrastructure. They found that port efficiency has the largest impact on bilateral trade. A one percent improvement in importer (exporter) infrastructure was found to increase imports, on average, by 0.67 (0.92) percent. However, they acknowledged that this might be as a result of selection bias since only coastal countries were included in the sample.

Lastly, Nordas and Piermartini (2004) expanded on an interesting finding by Limao and Venables (2001) – although they do not explicitly refer to this study. They constructed a bilateral dummy variable (for the overall infrastructure index and for the separate infrastructure indices) that takes on a value of one if the combined quantity of infrastructure of the trading partners is above average and zero otherwise. This indicates whether there is a threshold of combined quantity of infrastructure (as is possibly the case in Limao and Venables, 2001). They found that country pairs that had an above average combined infrastructure traded 1.36 times more than country pairs which had a below average combined infrastructure. However, this variable in effect captures how much the maximum level of infrastructure matters in determining trade flows. The construction of the dummy variable uses the combined infrastructure of the trading partners, thus if one trading partner has sufficiently good infrastructure the country pair will have above average infrastructure.

Although Nordas and Piermartini (2004) do include some interactions variables in their final set of regressions, for the most part they follow the standard procedure in the literature of including exporter and importer infrastructure variables (see also Francois *et al*, 2007 and Limao and Venables, 2001). This may be a misspecification leading to an omitted variable bias. Buys *et al* (2006) used a minimum quality road index between trading nations in their simulation of the trade-expansion potential of an integrated road network in Africa. They argued that this provides a more accurate reflection than using an average road quality index. However, only including the minimum quality road index is also a misspecification as it ignores the infrastructure of the other trading partner. As shown in Limao and Venables (2001) and Nordas and Piermartini (2004), the infrastructure of the exporter *and* the importer matters. Thus it is also necessary to include a maximum road index variable in order to capture the effect of the road quality of both bilateral partners on trade. Buys *et al* (2006) used a gravity model to obtain estimates of the effects of road transport quality and road distances on trade. This was done using African trade data from 2000 to 2003. These estimates were then used to calculate the current trade flows in the inter-city network and then to simulate the effect of a continental upgrading of the road network in Africa. They found that such an upgrade would expand overland trade flows by approximately $250 billion over 15 years, whilst financing the program would require about $20 billion initially and an additional $1 billion annually for maintenance.

However, Buys *et al* (2006) and Nordas and Piermartini (2004) fail to control for the zeros trade flows between certain countries. Westerlund and Wilhelmsson (2006) argued that the OLS estimates become biased if the zero observations are simply ignored or eliminated. Ignoring or eliminating the zero trade flows would be acceptable if the cases of zero exports occurred randomly. However, this is not the case as countries with high transport costs are less likely to trade. Thus using only countries that do trade constitutes a self-selected sample rather than a random sample. This non-random screening of data results in biased estimates (Coe and Hoffmaister, 2007). In order to deal with the number of zero bilateral trade flows Francois *et al* (2007) used a Heckman selection model. They used panel data from 1988 – 2002 to determine the effect of infrastructure and institutional quality on the pattern of trade. They found that transport infrastructure mattered in determining not only trade volumes, but also whether trade occurs at all. A one percent increase in the exporter's (importer's) infrastructure was found increase exports by 0.176 (0.178), whilst it improved the probability of trade occurring by 0.038 (0.057).

The results of Buys *et al* (2006) also suffer from an omitted variable bias as they did not include any multilateral resistance variables. Anderson and van Wincoop (2003) showed that not including the multilateral resistance variables in the gravity model means that these variables are captured by the regression residual. These omitted terms are correlated with the trade-cost term in the model, thus biasing the estimates of trade costs and all its determinants.

2.5) A focus on manufactures

Elbadawi (1999) argued that manufactured exports are more capable than traditional primary exports in supporting sustained overall economic growth. Due to higher price elasticities of demand and supply manufactured goods are less susceptible to price variability than primary goods. This is particularly relevant to African countries as several commodities which African countries relied on saw a severe decline in price in the previous decade. Between 1990 and 2000 cocoa, sugar and copper prices fell by 25 percent whilst coffee prices fell by 9 percent (Morrissey and Mold, 2006). It should be noted that these commodities are currently in a major upswing as prices of food and other commodities soar. However, this highlights the point made by Elbadawi (1999) about the price variability in primary products. Deaton (1999) argued that the understanding of commodity prices and the ability to effectively forecast price movements are currently inadequate. This lack of understanding has made it difficult to construct good policies, especially during price fluctuations. Deaton (1999: 26) argued that "the difficulties of handling fluctuations are so severe, and policy-making in African countries so dysfunctional, that price booms and price slumps are equally to be feared."

Wood and Mayer (2001) used a simple OLS regression to find the determinants of manufactures using a sample excluding African countries. These coefficients were then applied to the African characteristics in order to calculate an expected level of exports for each African country (given its human and natural resources). This was compared against the actual exports structure. Looking at the manufactures sector and Wood and Mayer (2001) found that on average manufactures formed a smaller part of exports than expected. For example; eight countries had a predicted manufactures export share of 26 percent but only averaged 3 percent. Thus even after taking into account the human and natural resource endowments, which they argued give most African economies a comparative advantage in primary products rather than manufactures, Wood and Mayer (2001) could not explain the low levels of manufactures in most African countries. When investigating the causes of variation between the expected and actual levels of manufactures they found that lack of infrastructure, macroeconomic mismanagement (particularly of the exchange rate) and ineffective administration appeared to cause the shortfall between the actual and predicted values (whilst geography and sector bias of trade policies had little to no effect). The discrepancy between actual and predicted export shares led the authors to conclude that growth in manufactured exports could make a large contribution to the growth of total exports. This in turn would boost aggregate growth (they argued that the causality can run both ways, higher aggregate growth can lead to higher export growth and *vice versa*). Therefore, even if Wood and Mayer (2001) are correct in arguing that Africa's comparative advantage lies in primary products (which many papers disagree with, see Bloom and Sachs, 1997 and Elbadawi, 1999) - improving infrastructure is still likely to have a significant and positive effect on the manufacturing sector.

2.6) Summary

This section has examined some of the main literature on infrastructure, transport costs and trade and has complimented these findings with recent data. Africa has been marginalised in terms of exports. In order to boost exports the main constraints should be identified and addressed. One of the major constraints for African exports is the high transport costs, which is largely due to the poor levels and quality of infrastructure. Poor infrastructure also determines what Africa exports and may well be partly to blame for the poor performance of the manufactures sector.

In order to calculate the effect of infrastructure on trade several key points are highlighted. Firstly, in order to avoid biased estimates one has to deal with the zero bilateral trade flows that are present in trade data. Secondly, including only the importer and exporter infrastructure in the gravity model may not adequately address the interaction between the infrastructures of trading nations. To better capture these interactions it is argued that the minimum and maximum bilateral infrastructures should be included into the gravity model.

Lastly, multilateral resistance variables or country dummies need to be included into the gravity model in order to avoid an omitted variable bias.

3) Theory: The Gravity Model

The gravity model provides the main link between trade barriers and trade flows (Anderson and van Wincoop, 2004). Below follows a brief derivation of Anderson and van Wincoop's (2003) theoretical gravity model, taken mainly from Feenstra (2002):

The two main assumptions of the theoretical gravity model are that each country produces unique product varieties and that consumers have identical, homothetic preferences which are approximated by a CES utility function.

The utility function for country j is:

$$(1)\ U^j = \sum_{i=1}^{C} N^i (c^{ij})^{(\sigma-1)/\sigma}$$

where c^{ij} denotes total consumption of any product sent from country i to country j and σ is the elasticity of substitution across all goods. It is assumed that all products exported by country i sell for the same price, p^{ij}, in country j. Furthermore all products produced in country i, N^i where i=1, …, C, face the same trade costs.

The representative consumer in country j maximises (1) subject to the budget constraint:

$$(2)\ Y^j = \sum_{i=1}^{C} N^i p^{ij} c^{ij}$$

where Y^j is the aggregate expenditure and income in country j (assuming balanced trade). The relationship between domestic and foreign prices (p^i and p^{ij} respectively) is assumed to be $p^{ij} = T^{ij} p^i$, where $T^{ii} = 1$ and $T^{ij} > 1$. This indicates that T^{ij} units of the product must be shipped to country j in order for one unit to arrive, as $(T^{ij} - 1)$ units are lost (or 'melts') along the way (this is tantamount to the "iceberg" model of transport costs).

Maximising (1) subject to (2), the following expression of the demand for each product c^{ij} can be derived:

$$(3)\ c^{ij} = (p^{ij} / P^j)^{-\sigma} (Y^j / P^j)$$

where P^j refers to country j's overall price index, defined as:

$$(4)\ P^j = \left(\sum_{i=1}^{C} N^i (p^{ij})^{1-\sigma} \right)^{1/(1-\sigma)}$$

The total value of exports from country i to country j is $X^{ij} = N^i p^{ij} c^{ij}$, substituting (3) and (4) into this gives a first version of the gravity model:

(5) $X^{ij} = N^i Y^j (p^{ij} / p^j)^{1-\sigma}$

The assumption of iceberg trade costs means that the output of the firm exceeds the net amount received by the consumer, these are related by:

(6) $y^i = \sum_{j=1}^{C} c^{ij} T^{ij}$

Multiplying both sides by p^i gives $p^i y^i = \sum_{j=1}^{C} c^{ij} p^{ij}$, which shows that the value of the output of the firm (using f.o.b. prices which are before trade costs) is equal to the expenditure of consumers (using c.i.f. prices which are after trading costs).

In order to find a solution for the unknown prices p^i the following relationships are used: Country i's GDP is denoted by $Y^i = N^i p^i y^i$, world GDP by $Y^w = \sum_{j=1}^{C} Y^j$ and country i's share by of world GDP by $s^i = Y^i / Y^w$. If we assume that transport costs are symmetric, i.e. $T^{ij} = T^{ji}$ then an implicit solution to the market clearing condition of (6) is:

(7) $\tilde{p}^i \equiv {(s^i / N^i)^{1/(1-\sigma)}} \big/ {\tilde{P}^i}$

and the price indexes are solved as:

(8) $(\tilde{P}^j)^{1-\sigma} = \sum_{i=1}^{C} s^i (T^{ij} / \tilde{P}^i)^{1-\sigma}$

Substituting (7) into (5) gives Anderson and van Wincoop's (2003) theoretical gravity model:

(9) $X^{ij} = s^i Y^j \left(\frac{T^{ij}}{\tilde{P}^i \tilde{P}^j} \right)^{1-\sigma} = \left(\frac{Y^i Y^j}{Y^w} \right) \left(\frac{T^{ij}}{\tilde{P}^i \tilde{P}^j} \right)^{1-\sigma}$

where $\tilde{P}^i$ and $\tilde{P}^j$ are price indexes. Anderson and van Wincoop (2003) refer to these as "multilateral resistance variables" since they depend on all bilateral resistances $\{T^{ij}\}$, including those not directly involving i.

The main result is therefore that bilateral trade, once the size of the economies have been controlled for, is determined by trade barriers. Specifically it is the trade barriers between two trading countries relative to the average trade barriers faced by these countries that determine the extent of bilateral trade (Anderson and van Wincoop, 2003).

The final step in the theoretical development of the gravity equation is to model the unobserved trade cost factor T^{ij}. In order to test the impact of infrastructure on trade Limao and Venables (2001) defined trade costs as follows:

(10) $T^{ij} = f(I^i, I^j, \theta^{ij})$

where I^i and I^j are the infrastructure of country i and j respectively and θ^{ij} is a vector of other characteristics relating to trade costs between country i and j. As argued above the specification of Limao and Venables (2001) may not adequately capture the interaction of the infrastructure variables. This paper proposes that the following functional form improves on the standard specification by capturing the interaction of infrastructure and its effect on transport costs:

(11) $T^{ij} = f(\min(I^i, I^j), \max(I^i, I^j), good\_transinf^{ij}, \theta^{ij})$

where $good\_transinf^{ij}$ is a dummy variable which takes on the value of 1 if both countries have above average infrastructure and zero otherwise. An *a priori* expectation is that the minimum quality of infrastructure between two trading countries matters most for trade. The majority of transport costs are likely to occur in the country with the lowest quality of infrastructure (due to, for example, time delays). Furthermore the minimum quality of infrastructure will also impact on the transport costs for the whole trip by determining the type of transport used. For example, the size and depth of a port determines the type of freight ship used. If a port is small this means that a smaller freight ship has to be used, regardless of the size of the port of the trading partner. This means that companies are not able to fully exploit the large economies of scale that exist in transportation. The maximum quality of infrastructure is also expected to matter for trade, although to a lesser extent. At least some of the transport costs are likely to occur in the country with the better infrastructure.

In order to get the gravity equation (9) into a more manageable form (11) is substituted into (9) and both sides are logged. The result (12) provides the basis of the estimation of this paper.

$$\begin{aligned} &\ln X^{ij} = k + \ln Y^i + \ln Y^j + (1-\sigma)\ln d^{ij} + (1-\sigma)\ln \min(I^i, I^j) \\ (12)\quad &+(1-\sigma)\ln \max(I^i, I^j) + (1-\sigma)\ln goodI^{ij} + (1-\sigma)\ln \theta^{ij} \\ &-(1-\sigma)\ln \tilde{P}^i - (1-\sigma)\ln \tilde{P}^j \end{aligned}$$

where k is a constant ($-\ln Y^W$). The estimation section below will provide an estimation strategy for the multilateral resistance variables as well as expand on θ^{ij}, the vector of other characteristics that influence trade costs. This will include an African dummy and some interaction variables. Equation (12) will also be manipulated to take account of the heterogeneity of goods and infrastructure.

4) Estimation

4.1) The Gravity Model

In order to estimate (12) the multilateral resistance variables need to be included. These indices are unobserved, but can be model through one of three methods: firstly, by including published data on price indices. Secondly, by solving the multilateral resistance variables as a function of observable trade costs and using a non-linear least squares estimation technique (as done by Anderson and van Wincoop, 2003) or thirdly, by using country fixed effects to account for unobserved differences in the countries (a procedure first employed by Harrigian, 1996). Feenstra (2002) compared the latter two methods on a dataset containing inter- and intraregional trade between Canada and the United States. He found that the country fixed effects method produced consistent estimates of the average border effects across countries and therefore argued that (along with its ease of use) it can be considered as the preferred empirical model.

θ^{ij} is estimated by including 6 other variables into the gravity model. Some of the transport costs are captured by a measure of distance between countries (*ldist)*, a dummy variable for countries that are landlocked (*dlocked)* and a dummy variable for countries that share a common border (*dborder*). Information costs are captured by a common language dummy variable (*dcomlang_off)* and other trade costs are captured by a dummy for bilateral agreements (*dbilateral).* An Africa dummy variable taking on the value of one if the exporter is from Sub-Saharan Africa *(dssa)* and zero otherwise is included as African countries may face different trade costs. These variables form the basic regression:

$$\begin{aligned} X_{ij} &= \alpha_0 + \beta_1 ldist_{ij} + \beta_2 dlocked_{ij} + \beta_3 dborder_{ij} + \beta_4 dbilateral_{ij} \\ &+ \beta_5 dcomlang\_off_{ij} + \beta_6 dssa_i + \beta_7 D_i + \beta_8 D_j + \eta_{ij} \end{aligned} \quad (13)$$

where X_{ij}=total exports and D_i and D_j are country exporter and importer dummy variables respectively.

The full estimation includes the minimum and maximum quality variables (*min_ltransinf* and *max_ltransinf*) as well as the dummy variable *good_transinf.* The full model also includes two more variables in the θ^{ij} term. Two interaction variables (*min_ltrasinf*dssa* and *max_ltransinf*dssa*) are included as infrastructure in Africa may affect trade costs differently than the rest of the world. The main estimation therefore has the following form:

$$\begin{aligned} X_{ij} &= \alpha_0 + \beta_1 ldist_{ij} + \beta_2 dlocked_{ij} + \beta_3 dborder_{ij} + \beta_4 dbilateral_{ij} \\ &+ \beta_5 dcomlang\_off_{ij} + \beta_6 dssa_i + \beta_7 min\_ltransinf_{ij} \\ &+ \beta_8 good\_transinf_{ij} + B_9 max\_ltransinf_{ij} + \beta_{10} min\_ltransinf_{ij} * dssa_i \\ &+ \beta_{11} max\_ltransinf_{ij} * dssa_i + \beta_{12} D_i + \beta_{13} D_j + \eta_{ij} \end{aligned} \quad (14)$$

where X_{ij}=total export, manufactured exports or primary exports and D_i and D_j are country exporter and importer dummy variables respectively.

Next (14) is recalculated for each specific infrastructure variable rather than the composite infrastructure index. This is done with total, manufactured and primary exports as dependent variables, thus 12 regressions overall.

Helpman *et al* (2007) argued that one should not only control for selection bias, but also control for the heterogeneity of firms by including the share of firms exporting. Ignoring firm level heterogeneity assumes that all firms are affected the same way by trade barriers and country characteristics and therefore make the same decision whether to export their goods or not. They found that ignoring firm level heterogeneity biased the estimation results. Although this paper does not control for firm heterogeneity, it does control for product heterogeneity. This controls for the fact that trade barriers may affect goods (and therefore the firms that produce these goods) differently. Any further control for firm level heterogeneity is beyond the scope of this paper.

4.2) The Heckman Selection Model

For estimation purposes the gravity model forms part of the Heckman selection model. Helpman, Melitz and Rubinstein (2007) argued that studies lose important information by disregarding countries that do not trade. This non-random screening of the sample results in biased estimates as the coefficients reflect the selection effect and the level effect. Approximately 14 percent of the trade data used in this paper are zeros - which are disregarded in the process of taking logs. In order to take these zero trade flows into account a Heckman selection model is used. This model consists of two equations. The first equation is the relationship of interest, called the outcome equation, which in this case is the gravity model:

$$\begin{aligned} X_{ij} &= \alpha_0 + \beta_1 ldist_{ij} + \beta_2 dlocked_{ij} + \beta_3 dborder_{ij} + \beta_4\ dbilateral_{ij} \\ &+\beta_5 dcomlang\_off_{ij} + \beta_6\ dssa_i + \beta_7\ min\_\ ltransinf_{ij} \\ &+\beta_8 good\_transinf_{ij} + B_9 max\_ltransinf_{ij} + \beta_{10} min\_ltransinf_{ij} * dssa_i \\ &+\beta_{11} max\_ltransinf_{ij} * dssa_i + \beta_{12} D_i + \beta_{13} D_j + \eta_{ij} \end{aligned} \quad (15)$$

However, X^{ij} is observed if and only if a second unobserved variable exceeds a particular threshold:

$$\begin{aligned} z_{ij}^{*} &= w_{ij}^{'}\alpha + u_{ij} \\ z_{ij} &= \begin{cases} 1 \text{ if } z_{ij}^{*} > 0 \\ 0 \text{ otherwise} \end{cases} \end{aligned} \quad (16)$$

Equation (16) provides the selection equation:

$$(17)\quad \Pr(z_{ij} = 1) = \phi(\alpha' w_{ij})$$

which can be estimated using a Probit equation (Hopkins, 2005). The error terms (η_{ij} and u_{ij}) are assumed to be normally distributed ($N(0,\sigma)$ and $N(0,1)$ respectively) and have a correlation of ρ. If ρ is zero then standard OLS provides unbiased estimates, however if ρ is non-zero then the standard OLS estimators will be biased since the expected value of the error term η_{ij}, given the estimators, will no longer be equal to zero (Briggs, 2004). The Heckman selection model uses the information of the non-trading countries to improve the estimates of the gravity model. The inclusion of information from the selection equation in the outcome equation means that the estimates of the Heckman selection model are consistent, unbiased and asymptotically efficient (Briggs, 2004). For the estimation purposes of this paper **X** is bilateral export values and **Z** is a dummy variable taking on the value of 1 if bilateral trade occurs and zero otherwise.

4.3) The Selection Equation: Probit

The first stage of the Heckman procedure is estimated with a Probit equation that measures the probability of country *i* exporting to country *j* as a function of observable variables. These variables can be different from the variables determining how much a country trades. In fact, in order to avoid collinearity between the first and second stage of the Heckman procedure at least one variable is needed that can be legitimately excluded from the second stage of the procedure (Sales *et al,* 2004). Helpman *et al* (2007) found that the probability that two randomly drawn persons from country *i* and *j* share the same religion did not affect export volumes, but that it strongly influences the formation of trading relationships. The variable *lrel* (the natural log of the conditional probability that two persons from country *i* and *j* share the same religion) is therefore included in the Probit equation, but not in the gravity equation.

Francois *et al* (2007) found that institutions and infrastructures affect the probability of exports taking place. Therefore two institutional variables and two transport infrastructure variables (all logged) are included in the Probit regression (*linst_exp* ,*linst_imp* and *ltrans_exp, ltrans_imp* respectively). Based on Nordas (2006) the log of time to export (lexptime_exp) and log of time to import (limptime_imp) are also included in the Probit regression. Other variables included in the Probit are the log GDP of the exporter and importer respectively (*lgdp_exp* and *lgdp_imp*), the log of the geographical distance in kilometres between capital cities of country J and I (*ldist)* and dummy variables for being landlocked (*dlocked*), common language (*domlang_off*), colonial linkages (*dcolony*), neighbouring borders (*dborder*) and bilateral trade agreements (*dbilateral*). The equation has the following form:

$$\begin{aligned}(18)\quad \rho_{ij} &= P(z_i = 1) = \alpha_0 + \alpha_1 lgdp\_\exp_i + \alpha_2 lgdp\_imp_j + \alpha_3 l\exp time\_\exp_i \\ &+ \alpha_4 limptime\_imp_j + \alpha_5 linst\_\exp_i + \alpha_6 linst\_imp_j + \alpha_7 ltransinf\_exp_i \\ &+ \alpha_8 ltransinf\_imp_j + \alpha_9 ldist_{ij} + \alpha_{10} dlocked_{ij} + \alpha_{11} dcomlang\_off_{ij} \\ &+ \alpha_{12} dcolony_{ij} + \alpha_{13} dborder_{ij} + \alpha_{14} dbilateral_{ij} + \alpha_{15} lrel_{ij} + \eta_{ij}\end{aligned}$$

From the Probit estimation the inverse Mills ratio is obtained and is included in the gravity model. In this case (due to the distributional assumptions) the inverse Mills ratio is the ratio of the probability density function and the cumulative density function (Helpman *et al*, 2007). The inverse Mills ratio is estimated by multiplying the estimate of ρ (the correlation of the error terms) with the estimate of the standard error of the residuals in the gravity equation (Briggs, 2004). The inverse Mills ratio is thus not only a function of the observed variables, but also includes unobserved or unmeasured variables which are captured through the error term of the Probit equation (Sales *et al,* 2004). Including the inverse Mills ratio into the outcome equation therefore corrects for the sample selection problem of the gravity equation. Briggs (2004) argued that the inverse Mills ratio also provides an indication of the direction of the bias of standard OLS estimates. A positive (negative) coefficient for the inverse Mills ratio indicates that OLS estimates are biased upwards (downwards), since this indicates a positive (negative) correlation between the error terms ρ (the standard deviation of the error term in the gravity equation is always positive).

4.4) Poisson Pseudo Maximum Likelihood

Silva and Tenreyro (2006) argued that gravity models (and other constant elasticity models) should be estimated in its multiplicative form. They show that log-linearising (or any other non-linear transformation) of the gravity model in the presence of heteroskedasticity can generate biased estimates. This occurs as the expected value of the log of a random variable depends on the higher orders of its distribution. Therefore, in the presence of heteroscedasticy the transformed errors will be correlated with the covariates of the model leading to biased estimates. The use of country specific fixed effects is likely to reduce the severity of this problem, but Silva and Tenreyro (2006) show that the biases are still present when using the theoretical gravity model of Anderson and van Wincoop (2003).

They argued that it is therefore not advisable to estimate the coefficients using a log-linear model. Instead they suggest using a Poisson Pseudo Maximum likelihood (PPML) estimation technique. The PPML is not only consistent in the presence of heteroskedasticity, but also deals with zero values in the dependent variable. The estimates based of the Poisson likelihood are consistent even if the data does not follow a Poisson distribution. The PPML estimation technique is used as the main alternate to the Heckman selection model in this paper and will test the robustness of the results to alternate specifications.

4.5) Endogeneity

This paper assumes that infrastructure influences export volumes. However, the causality may well run the other way; high trade volumes might force the government or private sector to upgrade transport infrastructure. This means that infrastructure may be an endogenous variable and including it into the OLS regressions will result in biased and inconsistent estimates. The two way causal relationship between infrastructure and exports is made more complex by the use of the minimum and maximum infrastructure variables. Countries with average infrastructure are either captured in the minimum or maximum variable, depending on the trade partner, thus the causal link from exports to infrastructure is somewhat blurred for this group and it is not clear whether the minimum and maximum variables are in fact endogenous.

The functional form of the infrastructure variables also make it difficult to find suitable instrumental variables. Djankov *et al* (2006) used a gravity model to estimate the effects of time costs on trade. They used the number of documents required to export and import as instrumental variables for time costs. The number of documents required is also an applicable instrument for infrastructure. The number of documents needed to export is a measure of excessive bureaucracy that slows down the improvement in infrastructure, but is not as a result of higher export volumes as these requirements tend to be based on historical laws (Djankov *et al,* 2006). The correlation between the infrastructure of the exporter and the number of documents needed to export is 0.54. Francois *el al* (2007) noted that infrastructure is highly correlated with GDP and population. GDP and population of the exporter and importer can therefore also be used as instruments since these are not included in the gravity model. However, it is necessary to use lagged terms (in this case 2003 data are used) otherwise the GDP and population variables will also be endogenous as the causal relationship between exports and GDP or population can run both ways. The correlation between the infrastructure and GDP of the exporter is 0.73 whilst the correlation of infrastructure and the population of the exporter is 0.15. Results for the correlation of the importer variables are similar (see Appendix). Although number of documents needed, GDP and population could be used as instruments for the transport infrastructure of the exporter and importer; it is not clear that these are applicable for the minimum and maximum infrastructure variables.

Instead this paper follows a type of manual two stage least squares estimation. The first stage removes the variation of the infrastructure variables that could be correlated with the error term by regressing the infrastructure of the exporter (*ltransinf_exp*) on the number of documents required to export (*lexpdoc_exp*), GDP of the exporter in 2003 (*lgdp03_exp)* and the population of the exporter in 2003 (*lpop03_exp*). The same strategy is then repeated for the importer variables (see Appendix). From these results fitted values for the quality of exporter and importer infrastructure are obtained and these are used to create new minimum and maximum variables. In the second stage the new (predicted) minimum and maximum variables are included into the gravity model. These estimates will be unbiased since these variables are devoid of the variation that could potentially have been correlated with the error term in the gravity regression.

5) Data

The database used for the estimation in Section 6 consists of bilateral trade flows between 117 countries for 2005. The data was obtained from the UN Commodity and Trade Database (COMTRADE). Mirror data was used where export data was missing or unavailable. Despite using mirror data 2059 of the 13806 observations were zero trade flows, approximately 14 percent of the sample. Most of the observed zeros occur because not all countries trade with each other (for example no trade occurs between Azerbaijan and Trinidad and Tobago), however some of the zero observations are also due to a lack of trade data on specific countries. As is generally the case when using trade data, a *caveat* should be given on the quality of the data. Trade data is often of poor quality, missing or even purposefully inflated or deflated to serve other purposes.

Data on distance, population, common official languages, former colonies and border countries were obtained from CEPII Distance Databases whilst the religion data was obtained from the CIA World Factbook. Data on trade related capacity variables such as infrastructure, institutions and human capacity were obtained from the World Development Indicators, the Global Competitiveness Report (GCR) and the Doing Business Report. These data are mostly quality measures obtained from business surveys. For example, the quality of infrastructure is based on the results to the question: “general infrastructure in your country is (1 = underdeveloped, 7=as extensive and efficient as the world’s best).”

Following the methodology of Wilson *et al* (2003) two transport related infrastructure indices, *transinf_exp* and *transinf_imp* (referring to the infrastructure of the exporter and importer respectively), were constructed from the results of the Global Competitiveness Report. These indices consist of the combination of the port, air, rail and telecommunication infrastructure variables – all quality measurements. These variables all have equal weighting in the indices as this provides better transparency of method and because no theoretical or statistical arguments exist on how to aggregate these indexed inputs (Wilson *et al,* 2003).

From the two indices three new variables were created. *Min_ltransinf* and *max_ltransinf* is the natural log of the minimum and maximum value for each bilateral pair of *transinf_exp* and *transinf_imp*. The third variable is a dummy variable, *good_transinf*, which takes on the value of one if the infrastructure quality for both importer and exporter is above average. Although using the average as a cut-off point is an arbitrary choice it should provide some indication whether thresholds exist. Two interaction terms are also created by combining the minimum and maximum variables with the Sub-Saharan dummy variable (*min_ltransinf*dssa* and *max_ltransinf*dssa*).

Minimum and maximum variables were also constructed for the individual indicators of transport infrastructure, namely: port, air, rail and telecommunications along with individual good transport dummies. Thus twelve variables were created following similar methodology as above along with 8 interaction terms for each individual infrastructure.

6) Results

6.1) The general model

The estimation results for the general gravity model are presented below in Table 3. Results for the Probit regressions are not the main focus of this paper and are thus included in the Appendix. The coefficients of distance, landlocked, border and common language are all highly significant and have the expected signs, with the exception of the landlocked dummy in column 3 which is negative but not significant. The coefficients of distance and common language are similar to those found by Limao and Venables (2001) and Nordas and Piermartini (2004). The only coefficients which do not take on a 'standard' size are those of the landlocked dummy, which are much larger than comparative coefficients in Nordas and Piermartini (2004) and Francois *et al* (2007).

In the basic regression (column 1) there is no evidence that African exports differ significantly from non-African countries (given its characteristics). However, once the infrastructure variables are introduced (column 2) the African dummy coefficient becomes positive and significant. This is consistent with the findings by Coe and Hoffmaister (1998) who found that, in terms of North-South trade, African countries actually trade slightly more than expected. The picture changes somewhat when disaggregate data are used. The coefficient of the African dummy in the manufactured exports regression (column 3) is negative and significant. Thus African countries, given its characteristics, tend to export less manufactured goods than expected. This result is in line with Wood and Mayer (2001) who found that on average manufactures formed a smaller part of exports in African countries than expected. In contrast African countries trade more primary products than expected (column 4). This result highlights Africa's dependency on primary product exports, as Deaton (1999; 23) argued; "African economies export primary products, and most export little else."

The minimum and maximum infrastructure coefficients are consistently positive, significant and large. These results indicate that the infrastructures of both trading nations are important determinants of trade. At first glance it may seem that the minimum and maximum infrastructure matters almost equally for trade, but this is not the case. The coefficients show the effect of a small (equal) percentage change of the variables on exports. However, the absolute change in infrastructure due to an equal percentage change will always be larger for the maximum variable - which is greater than the minimum variable by construction. In order to have an equivalent change in infrastructure the minimum variable will need a substantially larger percentage increase. Despite this the coefficients of minimum infrastructure are greater than the coefficients of the maximum infrastructure variable, which is the main result of this paper: the minimum quality of infrastructure is the key determinant of transport costs. This seems to be especially true for manufactured exports, as the minimum coefficient is much larger than the maximum coefficient (column 3). Interestingly the impact of improving the minimum quality of infrastructure is less for manufactured goods than primary goods (column 4). This is a surprising result as it was expected that infrastructure would matter more for manufactured goods. It is not clear why this is the case; one possible explanation is that this result reflects that primary products (especially agricultural goods) are even more constrained by delivery times than manufactures because of the consumer's demand for fresh products. Furthermore non-agricultural primary products that are used as inputs in production are likely to face the same pressures from just-in-time business practises than manufactures, but the production or excavation of the primary goods are not necessarily near major exporting centres. These goods therefore have to travel further and are thus more dependent on transport infrastructure.

The coefficients of the minimum and maximum variables are very large. Although the coefficients are not directly comparable to any other studies, the coefficients for infrastructure in gravity models are generally much lower. The coefficients are large for several different reasons: Firstly, the infrastructure index differs from the indices used in other studies. Limao and Venables (2001) and Nordas and Piermartini (2004) used quantitative data such as percentage of paved road and number of main telephone lines per person. The infrastructure index used in Wilson *et al* (2005) is the closest to the infrastructure indices used in this paper. They construct an index using the GCR data on quality of port and air transport. The indices used in this paper also include data on rail and telecommunications infrastructure along with port and air transport infrastructure. The data are for 2005, rather than the 2000 data used by Wilson *et al* (2005) and the number of observations are double that used by Wilson *et al* (2005). Secondly, this model takes into account the zero observations in trade data by using a Heckman selection model. The coefficients of the inverse Mills ratios are significant, large and negative, indicating that standard OLS estimates which ignores the zero observations are biased downwards (Briggs, 2004). Thirdly, this paper corrects for a bias induced by not including country dummies or using multilateral resistance variables as argued Anderson and van Wincoop (2003). Estimating the Heckman model without country dummies results in significantly smaller coefficients (see Appendix). The bias of not including country dummies is therefore also a downward bias - lowering the coefficients. Lastly, the infrastructure coefficients may be larger because of the way the indices were constructed. This paper argues that using the minimum and maximum variable is a better way to model transport costs. Using exporter and importer infrastructure may therefore not fully capture the extent of the effect of transport costs on exports, thus resulting in smaller coefficients.

Table 3: Select results of Heckman selection model for total, manufactures and primary exports, 2005

Variable	Total	Total	Manufactures	Primary
	(1)	(2)	(3)	(4)
ldist	-1.465***	-1.468***	-1.286***	-1.670***
	(-41.51)	(-38.88)	(-10.20)	(-35.34)
dlocked	-2.872***	-1.259***	-1.343	-3.867***
	(-8.72)	(-4.34)	(-1.80)	(-7.50)
dborder	0.854***	0.849***	1.399***	0.987***
	(6.23)	(6.18)	(3.42)	(6.09)
dbilateral	0.156	0.148	-0.136	0.067
	(1.75)	(1.65)	(-0.53)	(0.63)
dcomlang_off	0.827***	0.823***	0.765***	0.736***
	(11.06)	(10.89)	(3.69)	(7.92)
dssa	0.437	0.714*	-2.413**	2.577***
	(1.44)	(2.26)	(-3.20)	(5.56)
min_ltransinf		8.118***	6.489***	8.370***
		(21.47)	(6.09)	(10.8)
good_transinf		0.031	0.01	0.182
		(0.29)	(0.04)	(1.3)
max_ltransinf		8.079***	5.000***	8.556***
		(20.19)	(4.44)	(10.41)
min_ltransinf2dssa		0.47	0.423	1.047
		(1.22)	(0.42)	(1.96)
max_ltransinf2dssa		0.074	-0.544	0.284
		(0.34)	(0.97)	(0.95)
mills				
lambda	-1.859***	-1.876***	-5.538***	-1.258***
	(-8.50)	(-7.69)	(-3.80)	(-6.28)
N	13243	13243	11592	13243

Source: Author's calculations
Note: ***, **, * marks significance at the 0.1, 1 and 5 percent level
Country fixed effects results are not included
t-stats are reported in parenthesis

The dummy variable *good_transinf* is positive but is not significant in any of the regressions. Thus there is no evidence of a threshold effect (the same regressions were attempted using the 40th and 60th percentile rather than the mean, but had similar results). The impact of infrastructure on trade was thus fully captured by the minimum and maximum variables. There is also no evidence that infrastructure affects African countries any differently than the rest of the world. Although the interaction coefficients were all positive, none were significant at the 5 percent level.

The above regressions were repeated with the sample restricted to African exports. This did not yield any useful results – mainly due to the low level of variation of the infrastructure variables. Since most African countries struggle with low quality of infrastructure restricting the sample size removes all variation. The inability to apply these variables to an Africa only sample is admittedly a shortcoming of this paper. The results are included in the Appendix for completeness sake.

6.2) The effect of port, air, rail and telecommunications infrastructure

The interpretation of the size of the minimum and maximum coefficients above should be done with care. Despite the justifications provided for the seemingly large infrastructure coefficients, an increase in the overall quality of infrastructure needs to come from an increase in one or more of the specific forms of infrastructure included in the index. By construction each specific form of infrastructure contributes equally to the infrastructure index and thus to trade, which is unlikely to be the case. Modelling the impacts of the specific forms of infrastructure is therefore more appropriate and will provide results that are more practically applicable. The results using specific forms of infrastructure are provided in Table 4.

Table 4: Select results of Heckman selection model, specific infrastructures and disaggregate data, 2005

	Total Exports				**Manufactures**				**Primary Products**			
	Port	Air	Rail	Tele	Port	Air	Rail	Tele	Port	Air	Rail	Tele
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ldist	-1.458***	-1.437***	-1.500***	-1.441***	-1.363***	-1.450***	-1.293***	-1.307***	-1.649***	-1.607***	-1.725***	-1.662***
	(-39.76)	(-37.11)	(-39.64)	(-39.11)	(-13.90)	(-39.07)	(-11.08)	(-11.61)	(-36.01)	(-34.55)	(-35.98)	(-36.42)
dlocked	-0.786**	-0.689**	-2.238***	-2.454***	1.069	-2.564	-2.436***	-0.529	-1.128**	1.568***	-5.241***	0.396
	(-3.05)	(-2.67)	(-9.43)	(-4.47)	(1.47)	(-1.76)	(-3.95)	(-0.33)	(-2.98)	(-4.1)	(-8.82)	(1.02)
dborder	0.858***	0.833***	0.846***	0.827***	1.312***	1.466***	1.375***	1.344***	0.997***	0.948***	0.986***	0.977***
	(6.25)	(5.68)	(6.29)	(5.95)	(4.1)	(9.85)	(3.75)	(3.63)	(6.13)	(5.68)	(6.16)	(6.02)
dbilateral	0.238**	0.219*	0.240**	0.228**	0.287	-0.213**	0.264	0.25	0.162	0.122	0.173	0.154
	(2.77)	(2.41)	(2.81)	(2.64)	(1.76)	(-2.60)	(1.41)	(1.32)	(1.56)	(1.15)	(1.67)	(1.48)
dcomlang_off	0.828***	0.770***	0.850***	0.809***	0.821***	0.900***	0.779***	0.768***	0.733***	0.647***	0.782***	0.741***
	(11.03)	(9.61)	(11.43)	(10.65)	(5.09)	(12.4)	(4.2)	(4.09)	(7.92)	(6.84)	(8.47)	(8)
dssa	-0.099	-0.228	-4.083***	-3.789***	0.787	-0.254	-2.237***	-2.513**	1.260***	1.863***	2.934***	1.636
	(-0.39)	(-0.82)	(-17.58)	(-11.88)	(1.2)	(-1.72)	(-3.47)	(-2.79)	(3.37)	(4.46)	(6.47)	(1.76)
min_	1.755***	2.215***	1.196***	-0.248	-0.666	5.138*	4.008***	2.060**	2.523***	2.028***	6.569***	-0.104
	(6.11)	(6.04)	(6.73)	(-0.25)	(-1.18)	(2.38)	(6.63)	(2.96)	(6.07)	(4.57)	(11.4)	(0.26)
good_	-0.087	0.404***	-0.026	0.088	-0.107	0.173*	0.079	0.04	-0.125	0.480***	-0.099	0.01
	(-1.19)	(5.51)	(-0.33)	(1.63)	(-0.75)	(2.27)	(0.44)	(0.32)	(-1.36)	(5.39)	(-0.99)	(0.14)
max_	1.703***	1.206**	1.417***	-1.14	-0.993	4.150*	3.558***	--	2.334***	0.192	6.932***	-0.662
	(5.48)	(2.85)	(7.91)	(-1.10)	(-1.59)	(2.02)	(5.89)	--	(5.22)	(0.38)	(11.84)	(-1.27)
min_*dssa	0.407	-0.069	0.684**	-0.681	0.183	-0.23	0.499	-1.457	0.463	0.734	0.696*	0.199
	(1.94)	(-0.21)	(3)	(-1.87)	(0.43)	(-0.32)	(0.96)	(-1.61)	(1.58)	(1.71)	(2.24)	(0.37)
max_*dssa	-0.304	0.969***	-0.048	0.368	-0.612	0.477	-0.447	-0.112	-0.229	0.938**	0.053	1.025*
	(-1.74)	(3.61)	(-0.39)	(1.11)	(-1.72)	(1.6)	(-1.59)	(-0.14)	(-0.96)	(2.67)	(0.32)	(2.16)
mills lambda	-1.861***	-2.271***	-1.609***	-2.056***	-4.323***	-5.477***	-4.946***	-5.008***	-1.301***	-1.794***	-0.959***	-1.292***
	(-8.07)	(-9.14)	(-6.83)	(-8.87)	(-3.96)	(-8.68)	(-3.91)	(-3.98)	(-6.13)	(-8.14)	(-4.37)	(-6.03)
N	13243	13243	13243	13184	11592	11066	11592	11554	13243	13243	13243	13201

Source: Author's calculation

Note: ***, **, * marks significance at the 0.1, 1 and 5 percent level
Country fixed effects results are not included
t-stats are reported in parenthesis

The coefficients of distance, border and common languages are robust to changes in the specification and are all similar to the results in Table 3. The coefficients of the landlocked dummy in columns 1 and 2 are lower (-0.786 and -0.689 respectively) and more inline with other studies. However, the landlocked dummy is not particularly robust to changes in the specification of the model as coefficients vary between highly negative (-5.24 in column 11) to positive, but not significant (1.069 in column 5).

The results for the African dummy are mostly consistent with the findings in Table 3, except for the coefficients of the total trade regressions. According to Table 4 African countries total exports tend to be less than other countries given its characteristics (columns 1 – 4). However, this result is not particularly robust as two of the four coefficients are not significantly different from zero. African countries also tend to export less manufactures than what would be expected (as was the case in Table 3). These results are also not robust as the African dummy coefficient is not significant in columns (5) and (6). However, the results suggest that there is scope for improvement in the export of manufactured goods. Lall (2005) argued that a better manufactured exports sector could make a large contribution to growth of exports and begin to combat Africa's marginalisation in world trade. Teal (1999:1) argued that "the issue as to how sub-Saharan African countries can enter the market for manufactures is one of the most important policy issues facing governments in Africa."

In contrast, African countries - conditional on their characteristics - export more primary products than non-African countries. Even though the African dummy remains positive in the primary product regressions, the findings above show that there is still scope to improve primary product exports by improving infrastructure. Diao *et al* (2003) argued that rapid growth in the agricultural sector is central for any strategy to reduce poverty and hunger on the African continent. They argued that poor infrastructure (along with poor institutions and protectionist policies of developed countries) is one of the major constraints to developing a strong agricultural export sector. An improvement in infrastructure will provide farmers with better market access and also decrease the price of imported food. In a time with souring food prices, which are likely to remain high for several years to come, getting access to cheaper food will be crucial for the poor in African countries.

The coefficients of the minimum and maximum variables of port, air transport and rail infrastructure are positive and significant (with the exception of ports in column 5). The coefficients of the minimum variables are generally greater than the coefficients of the maximum variables. This is consistent with Table 3 and reiterates the main finding that it is the minimum quality of infrastructure that matters most for determining transport costs and therefore exports. As expected the specific infrastructure coefficients are much smaller. The most comparable result is from Buys *et al* (2004). Although they used a different infrastructure measurement (road quality), they use the same specification. They obtained a coefficient for the minimum road quality index of 2.062 which is similar to the results for total exports (columns 1, 2 and 3).

A couple of surprising results should be noted: Firstly, telecommunications is not significant in determining total exports, nor primary product exports. In fact for these regressions the coefficients are negative (column 4 and 12). Secondly, the quality of port infrastructure has no impact on manufactured exports. This is in contrast to the finding of Nordas and Piermartini (2004) that port infrastructure had the largest impact on bilateral trade. Lastly, some of the infrastructure coefficients are particularly large when using disaggregated data. The coefficients of air transport infrastructure (column 6) and rail infrastructure (columns 7 and 11) seem unduly large and should be treated with scepticism. One explanation for these odd results is that the quality of data is likely get worse when using disaggregated data. Disaggregated data are more susceptible to misspecification or errors at the border (where the data is collected) and the lower trade volumes mean that mistakes in the data could potentially have a greater effect on the estimation. Another explanation is that some of the odd results mentioned above may be due to an omitted variable bias. Since, for example, manufactured goods may be dependent on both rail and port infrastructure, only including one term could lead to biased results. Anderson and van Wincoop (2003) warned that using country dummies does not make the model more robust. A wrongly specified cost function, either in terms of functional form or set of variables included, will results in biased estimators. The estimators will be biased to the extent that the specification error is correlated to the trade costs variables.

The coefficient of the threshold dummy is consistently positive for air transport infrastructure. Thus if both trading partners have infrastructure that is above average quality they tend to trade 49.78 percent (from column 1) more than trading countries who do not both have above average infrastructure. In contrast to Table 3 there is some evidence that improving certain infrastructures of African countries has a different effect to the rest of the world. Improving the minimum rail infrastructure has a larger effect on total and primary exports than the rest of the world (a one percent improvement results in a 0.684 and 0.696 percent increase in exports respectively). The large amount of landlocked African countries means that overland transportation is often necessary in order to export goods. Furthermore overland transport between African countries is often extremely costly or non-existent, thus it is no surprise that an improvement in the minimum quality of rail infrastructure has a larger effect on African countries. Improving the maximum quality of air transport infrastructure also has a larger effect on African total and primary product exports (the coefficients are 0.969 and 0.938 respectively). It is unclear why the maximum coefficients are significant when the minimum coefficients are not.

7) Sensitivity of results

7.1) Poisson Pseudo Maximum Likelihood

The results from the PPML estimation are shown in Table 5 and are generally similar to those obtained in Table 3. However, the coefficients of *ldist* are significantly smaller. This is consistent with the findings of Silva and Tenreyro (2006) that the coefficient of distance decreases when using a PPML model. Furthermore common language does not have a significant effect on exports according to the PPML model. The African dummy is positive in all 3 regressions, but is only significant for primary exports. The finding that African countries, given its characteristics, export more primary products than non-African countries is consistent with the results in Table 3 and 4.

The coefficients of the minimum and maximum variables are positive and significant for total exports and primary exports. The size of the coefficients however, differs somewhat from the Heckman selection model. The maximum coefficients are larger than the minimum coefficients, although as argued above this is likely to be as a result of the construction of the variables. In comparison to Table 3 the coefficients of the minimum and maximum variables are larger in the total exports regression (column 1) and smaller in the primary exports regression (column 3); however it is in the manufactured exports regression where there are major differences (column 4). The size of the coefficients of the minimum and maximum variables nearly double for manufactured exports – but is not significant. The large jumps in the size of the coefficients are puzzling and indicate that the results of the manufactured export regressions are not robust to changes in the specification of the model.

The interaction terms indicate that improving the minimum infrastructure has a smaller effect on African total and manufactured exports. This differs from the Heckman selection model results, which (although mostly insignificant) tended to indicate that infrastructure improvements have a larger effect on African countries than non-African countries.

Table 5: Select results from the PPML and adapted two stage least squares models, 2005

	PPML			**Adapted 2SLS**		
	Total	**Manufactures**	**Primary**	**Total**	**Manufactures**	**Primary**
	(1)	(2)	(3)	(4)	(5)	(6)
ldist	-0.619***	-0.582***	-0.881***	-1.394***	-1.267***	-1.585***
	(-13.03)	(-12.33)	(-19.45)	(-27.96)	(-9.70)	(-31.51)
dlocked	-3.523***	-2.99	-3.549***	1.606***	2.189*	-2.558***
	(-5.16)	(-1.79)	(-5.24)	(4.48)	(2.11)	(-4.09)
dborder	1.071***	1.042***	0.926***	0.844***	1.426***	0.983***
	(7.87)	(7.58)	(6.88)	(4.79)	(3.37)	(5.85)
dbilateral	0.430***	0.475***	0.23	0.129	-0.119	0.041
	(3.88)	(3.97)	(1.85)	(1.13)	(-0.45)	(0.38)
dcomlang_off	0.063	-0.007	0.284	0.725***	0.754***	0.629***
	(0.41)	(-0.04)	(1.84)	(7.41)	(3.52)	(6.49)
dssa	3.398	5.911	3.513**	-2.895***	-3.859***	-7.009***
	(1.91)	(0.73)	(2.91)	(-7.53)	(-4.19)	(-10.29)
min_ltransinf	8.411***	16.075	5.208***	10.070***	15.712***	12.071***
	(4.24)	(1.73)	(4.64)	(23.3)	(11.67)	(17.74)
good_transinf	-0.364	-0.642	-0.147	-0.059	0.225	0.034
	(-1.09)	(-0.72)	(-0.49)	(-0.57)	(1.03)	(0.31)
max_ltransinf	10.337***	18.121	7.110***	8.109***	13.890***	9.981***
	(5.34)	(1.96)	(7.39)	(16.27)	(9.73)	(15.03)
min_ltransinf2dssa	-1.794*	-2.703**	0.248	0.663	0.759	1.211*
	(1.97)	(-2.92)	(0.24)	(1.4)	(0.73)	(2.32)
max_ltransinf2dssa	-0.224	-0.358	0.272	0.286	-0.668	0.579*
	(-0.23)	(-0.42)	(0.26)	(1.14)	(-1.22)	(2.09)
mills	--	--		-2.726***	-5.727***	-1.888***
lambda	--	--		(-7.87)	(-3.81)	(-7.51)
N	13805	13805	13731	13243	11592	13243

Source: Author's calculation

Note: East Timor is excluded from the two stage least squares regression due to lack of data.
t-stats are reported in parenthesis

7.2) Endogeneity

Table 5 also shows the results from the adapted two stage least squares estimation. In contrast to the PPML results the coefficients of *ldist* are the same size as found in Table 3 (nearly double the size of the PPML coefficients). The coefficient of common language is also significant and comparable to the results in Table 3 and 4. The landlocked dummy variable is once again sensitive to the specification as the coefficients of the total and manufactured regression are positive and large (column 4 and 5).

The coefficient of the African dummy is negative and significant in all the adapted two stage regressions. It is therefore not clear from the results of this paper whether the overall exports of African countries are greater or less than expected. Looking at the disaggregated data there seems to be evidence that African countries export less manufactures than expected (column 5), but this result is not robust. The coefficient of the African dummy is negative and significant for the primary product regression (column 6); this is in contrast to all the other results.

The coefficients of the predicted minimum and maximum variables are substantially larger than the coefficients from the Heckman selection model in Table 3. The sizes of the coefficients should be treated with scepticism as they seem unduly large. However, the main result of this paper is still consistent. The coefficients of the minimum variable are larger than the coefficients of the maximum variable. This indicates that the minimum quality of infrastructure between two trading partners matters most for transport costs and therefore trade.

There is no evidence of a threshold effect of infrastructure. This is consistent with the findings in Table 3. There is also little evidence that improving the infrastructure of African countries has a different effect to the rest of the world. According to the adapted two stage least squares model it is only in primary product exports (column 6) where African countries benefit more from an improvement in infrastructure than the rest of the world.

8) Simulating Potential Benefits from improving infrastructure

"*Africa needs a deliberate, systematic and concerted effort at the practical level to integrate, upgrade and modernize regional infrastructure so that it becomes the catalyst for Africa's growth. The regionally integrated corridor approach offers prospects for speedier integration of infrastructure systems in Africa." (*Simuyemba 2000: 3)

Although the focus of this paper is on African exports, the simulations are restricted to SADC countries. This is done as it is at the regional level where the policy implications of this paper are most applicable. The small size, high number of landlocked countries and poor infrastructure in African countries presents development challenges which are not easily overcome at the national level. A regional approach is therefore necessary to allow countries to upgrade infrastructure and improve their export performance. Regional bodies such as the Southern African Development Community (SADC) are the more likely to be able to coordinate regional spending on infrastructure, rather than it happening on a bilateral basis or within larger organisations such as the African Union. Furthermore, it is at a regional level where the political will towards regional integration and increased trade is likely to be the strongest. For example, all SADC member states have agreed on the SADC Protocol on Transport, Communications and Meteorology (SADC, 1996). This protocol includes the development of a regional transport master plan to meet trade and development requirements in the region. SADC infrastructure development programs aim to address infrastructure bottlenecks along prioritised corridors. These include ports, railways, road and facilities linked to inland waterways.

One possible way of simulating improved infrastructure is by increasing all infrastructure variables by a given percentage which is analogous to the CGE models. However, as Wilson *et al* (2003) argued, this does not provide useful results as it means that countries which already have good quality infrastructure will also improve. This method is not suitable for simulating the impact of improving the infrastructure of low quality countries. Buys *et al* (2006) increased the road quality of all countries with low levels up to a minimum level. However, the minimum level that they chose was ambitious at best. Buys *et al* (2006) chose a minimum value so high that 39 of the 42 countries in their sample fell below this level and thus had a simulated increase in road quality. Their simulated upgrades required a 5 fold increase in the quality of the road infrastructure for 7 countries and the largest simulated increase was 2400 percent! This paper follows Wilson *et al* (2003) by increasing the quality of infrastructure of all the below average SADC members halfway up to the SADC average. The CES assumption means that the coefficients of the regression can be applied to the individual countries. However, one drawback is that this simulation uses the regression results from the full (world) sample. Using the coefficients of a regression with a sample of only African or SADC countries would be more appropriate. However, as mentioned above such regressions do not provide usable results. The simulated improvements are shown in Table 6, 7, 8 and 9. One should keep in mind the extent of the simulated changes and the number of countries in the simulation when reviewing the results. For some countries the simulated upgrades are extensive and therefore large changes in exports will not be surprising.

The simulation focuses on the impact of improving port, air transport or rail infrastructure on total exports from SADC (Table 4, columns 1 – 3). The impact of the simulated improvements on intra-SADC trade and trade with the rest of the world is shown in Table 6. Improving port facilities and inland waterways has the biggest impact on intra-SADC trade, boosting exports by 15.25 percent, whilst improving rail infrastructure leads to the biggest increase in exports to the rest of the world (15.68 percent). Imports from the rest of the world generally increased by less than exports to the rest of the world, thus indicating a terms of trade improvement (excluding intra-SADC trade).

Table 6: Overall effect of simulation

Exports	Port	Air	Rail
Intra-SADC	15.25%	9.56%	12.22%
SADC to RoW	7.84%	7.47%	15.68%
RoW to SADC	3.42%	3.66%	7.66%

Source: Author's calculation

Table 7 shows the extent of the simulated port changes. Simulating increases in the port variable is made difficult by how the port variable is defined. The ports variable is based on the question "port facilities and inland waterways in your country are (1=underdeveloped, 7= as developed as the worlds best)" (World Economic Forum, 2008). For landlocked countries this question measures the ease of access to port facilities and inland waterways. Since a country such as Lesotho is landlocked and has no usable inland waterways, the port variable captures access to ports in South Africa and Mozambique. Thus the simulated increase in the ports variable could well capture improvements in road or rail infrastructure or even less border delays or paperwork. The ports variable is therefore not a 'clean' measure and should only be used as a rough indicator of the effect of improvements in port infrastructure. A more troublesome problem is that the port variable may reflect a rating of the quality of infrastructure of the nearest port or inland waterway system. This does not seem to be the case; Lesotho's closest port is in Durban (South Africa), however Lesotho has a score of 2.8 (out of 7) and South Africa has a score of 4.4. Thus the Lesotho score seems to be a reflection of *access* to the South African ports rather than a ranking of the quality of South African ports.

Although Lesotho and Zambia had the same improvement in port infrastructure, Zambia had a greater improvement in total exports and Balance of Payments. This occurs since Zambia has relatively stronger trade links with the rest of SADC than Lesotho (which exports mainly to the United States). Thus Zambia benefits more from the simulated infrastructure increases in other SADC countries. Malawi experiences the biggest terms of trade loss as the Balance of Payments decreases by 46.2 percent. This highlights an important point. Improvements in transport infrastructure provide countries with better access to global markets. However, it also provides the global market better access to the domestic market. It is thus possible that the terms of trade may worsen when infrastructure is improved. This, in turn, could lead to a currency depreciation. Furthermore, the actual improvement of infrastructure may itself require greater imports of equipment and materials, which will also lead to a worsening of the current account. A stable macroeconomic environment is therefore necessary to be able to offset possible stress that might arise on the current account and the domestic currency due to large infrastructure projects.

Table 7: Simulation results for Port and inland waterways infrastructure

	Country	Simulated increase (log change)	New Total Exports (US$, millions)	% Change	New Total Imports (US$, millions)	% Change	% B.O.P
1	Zambia	27.99%	2671.96	51.07%	2206.03	50.57%	53.49%
2	Lesotho	27.99%	756.55	49.13%	270.44	49.37%	48.99%
3	Zimbabwe	14.11%	1728.07	28.41%	2544.89	27.38%	-25.27%
4	Malawi	14.11%	624.02	26.36%	850.43	31.09%	-46.20%
5	Angola	11.82%	25452.36	20.68%	9308.41	20.75%	20.64%
6	Mozambique	5.68%	565.58	13.09%	2568.89	10.58%	-9.89%
7	Botswana	3.84%	4756.33	7.89%	3355.83	7.67%	8.42%
8	South Africa	--	50281.35	2.36%	50383.59	0.87%	87.62%
9	Namibia	--	2477.59	1.89%	2589.18	0.34%	25.00%
10	Gambia	--	5.10	1.29%	458.28	0.01%	0.00%
11	Kenya	--	2979.21	0.84%	5003.31	0.18%	0.77%
12	Portugal	--	35457.72	0.61%	62525.76	0.04%	0.70%
13	Tanzania	--	1479.38	0.55%	3033.66	1.58%	-2.59%
14	Benin	--	251.30	0.30%	2222.53	0.00%	0.04%
15	Uganda	--	636.53	0.16%	1412.09	0.05%	0.04%

Source: Author's calculations

As expected the countries with the largest simulated change in air transport infrastructure have the greatest increase in exports. Lesotho's exports increase approximately 75 percent after the 34 percent improvement in the quality of air transport infrastructure. Zambia again benefits from close trade ties with other SADC countries as exports increased by 2 percent, despite it not being involved in the simulation. South Africa and Namibia also improved exports as a result of the increased air transport infrastructure in the low quality countries. The Balance of Payments effect is mostly positive as most of the countries are net exporters.

Table 8: Simulation results for air transport infrastructure

	Country	Simulated increase (log change)	New Total Exports (US$, millions)	% Change	New Total Imports (US$, millions)	% Change	% B.O.P
1	Lesotho	34.29%	892.72	75.97%	318.71	76.04%	75.93%
2	Zimbabwe	13.55%	1760.69	30.83%	2601.95	30.24%	-29.02%
3	Angola	10.08%	25792.59	22.29%	9431.96	22.35%	22.25%
4	Mozambique	8.46%	604.97	20.97%	2773.29	19.37%	-18.94%
5	Malawi	6.90%	576.33	16.70%	765.03	17.93%	-21.85%
6	Tanzania	2.60%	1559.00	5.96%	3160.08	5.82%	-5.68%
7	Zambia	--	1806.85	2.16%	1490.22	1.71%	4.31%
8	Namibia	--	2473.71	1.73%	2584.75	0.17%	25.37%
9	South Africa	--	49841.25	1.47%	50251.36	0.61%	50.34%
10	Botswana	--	4464.21	1.26%	3126.46	0.31%	3.57%
11	Gambia	--	5.08	0.75%	458.24	0.01%	0.00%
12	Portugal	--	35480.50	0.68%	62514.07	0.02%	0.82%
13	Kenya	--	2969.67	0.52%	5000.85	0.13%	0.42%
14	Benin	--	251.37	0.33%	2222.54	0.00%	0.04%
15	Uganda	--	637.45	0.30%	1412.88	0.10%	0.06%

Source: Author's calculation

Looking at rail infrastructure; Lesotho had the biggest change in exports and this also resulted in an improvement in its Balance of Payments (BOP). Namibia, Zimbabwe and South Africa all benefited from increased exports of over 2 percent despite receiving no increase in the quality of domestic infrastructure. This highlights that all SADC members benefit by increasing the quality of infrastructure in low quality countries.

Table 9: Simulation results for rail infrastructure

	Country	Simulated increase (log change)	New Total Exports (US$, millions)	% Change	New Total Imports (US$, millions)	% Change	% B.O.P
1	Lesotho	28.85%	781.9397	54.13%	279.4162	54.33%	54.02%
2	Angola	24.59%	30792.86	46.00%	11249.5	45.93%	46.04%
3	Zambia	20.71%	2479.979	40.21%	2036.752	39.01%	46.02%
4	Mauritius	20.71%	2668.753	37.46%	3433.637	38.72%	-43.28%
5	Malawi	17.16%	655.872	32.81%	880.8999	35.79%	-45.31%
6	Mozambique	5.48%	566.6204	13.30%	2566.663	10.48%	-9.71%
7	Tanzania	5.48%	1625.153	10.46%	3313.954	10.97%	-11.47%
8	Namibia	--	2520.225	3.64%	2585.449	0.19%	56.16%
9	Zimbabwe	--	1389.576	3.25%	2032.647	1.74%	1.38%
10	South Africa	--	50062.75	1.92%	50303.9	0.71%	70.80%
11	Portugal	--	35712.66	1.33%	62537.36	0.06%	1.59%
12	Kenya	--	2992.611	1.29%	5010.775	0.33%	1.06%
13	Benin	--	252.1865	0.66%	2222.639	0.01%	0.08%
14	Madagascar	--	765.4429	0.62%	1291.201	2.89%	-6.38%
15	Gambia	--	5.067847	0.59%	458.3164	0.02%	-0.01%

Source: Author's calculation

The simulations show that if the policy maker's goal is to increase intraregional trade then they should focus on upgrading the transport infrastructure of the countries with the worst quality in the region. However, it also highlights the possible danger of decreased transport costs to the current account as many countries in the simulation experienced a worsening of their Balance of Payments.

9) Conclusion

This paper has examined the links between infrastructure, transport costs and trade flows, with a particular focus on African trade. Amadji and Yeats (1995) argued that much of the blame for Africa's marginalisation in trade was due to high transport costs. Limao and Venables (2001) found that transport costs are, to a large extent, determined by infrastructure. The main objective of this paper was to establish how country infrastructures interact in determining transport costs and therefore trade flows. This was done by constructing variables of the minimum and maximum quality of infrastructure between bilateral trading partners. These variables were included in a theoretical gravity model as specified by Anderson and van Wincoop (2003). The gravity model formed the outcome equation of a Heckman selection model, which was used deal with the number of zeros that are present in bilateral trade data.

The results showed that it is the minimum quality of infrastructure that matters most for exports between bilateral trade partners. This result makes intuitive sense; the bulk of transport costs are determined in the country with the lowest quality of infrastructure since this is where the greatest time delays and loss of goods are likely to occur. This finding is most applicable to regional agreements such as SADC which aim to boost intraregional trade and foster regional integration. The key policy conclusion is that regional integration schemes should focus on improving the regional infrastructure, with specific focus on the countries with the lowest quality infrastructure. The maximum quality of infrastructure between trading partners was also found to be a significant determinant of trade. Again this makes intuitive sense as the infrastructure of both countries matter for trade.

Similar results were found when the individual infrastructure indicators (ports, air transport, rail and telecommunications) were used. Port, air transport and rail infrastructure were all found to have a significant impact on trade. In particular it was found that the minimum quality of the individual infrastructure indicators is the largest determinant of trade flows. Air transport infrastructure was the only infrastructure variable to show evidence of a threshold effect. The main results of this paper were also robust when a Poisson Pseudo Maximum Likelihood model was used and when correcting for endogeneity.

This paper did not find consistent evidence that improving infrastructure in African countries had a different effect on trade than the rest of the world. The results generally indicated that African countries will benefit more from improved infrastructure, although these findings were rarely significant. Furthermore this paper did not find robust evidence that African countries export less than non-African countries. However, it was found that African countries, given its characteristics, tend to trade less in manufactures than expected. Even though this result was also not robust, it is consistent with the findings of Wood and

Mayer (2001) that manufactured exports is an area where African countries are currently underperforming. In contrast, African countries were found to export more primary products than expected. This result was robust to using individual infrastructure indicators and the PPML model, but not when correcting for endogeneity. The findings of this paper suggest that any strategy to improve overall, manufactured or primary product exports in Africa (which has the worst regional average in the world) will require an upgrading of the quality of transport infrastructure.

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10) Appendix

Table 10: Countries sample for Section 5

Albania	Germany	New Zealand
Algeria	Ghana	Nicaragua
Angola	Greece	Nigeria
Argentina	Guatemala	Norway
Armenia	Guyana	Pakisatn
Australia	Honduras	Panama
Austria	Hong Kong SAR	Paraguay
Azerbaijan	Hungary	Peru
Bangladesh	Iceland	Philippines
Belgium	India	Poland
Benin	Indonesia	Portugal
Bolivia	Ireland	Romania
Bosnia and Herzegovina	Israel	Russian Federation
Botswana	Italy	Serbia and Montenegro
Brazil	Jamaica	Singapore
Bulgaria	Japan	Slovak Republic
Burkina Faso	Jordan	Slovenia
Burundi	Kazakstan	South Africa
Cambodia	Kenya	Spain
Cameroon	Korea, Rep.	Sri Lanka
Canada	Kuwait	Sweden
Chad	Kyrgyz Republic	Switzerland
Chile	Latvia	Taiwan
China	Lesotho	Tajikistan
Columbia	Lithuania	Tanzania
Costa Rica	Macedonia, FYR	Thailand
Czech Republic	Madagascar	Trinidad and Tobago
Denmark	Malawi	Tunisia
Dominican Republic	Malaysia	Turkey
East Timor	Mali	Uganda
Ecuador	Mauritiania	Ukraine
Egypt	Mauritius	United Arab Emirates
El Salvador	Mexico	United Kingdom
Estonia	Moldova	United States
Ethiopia	Mongolia	Uruguay
Finland	Morocco	Venezuela
France	Mozambique	Vietnam
Gambia	Namibia	Zambia
Georgia	Netherlands	Zimbabwe

Table 11: Probit Results, 2005

	Total	Manufactures	Primary
lgdp_imp	0.207***	0.031**	0.219***
	(17.15)	(3.27)	(19.88)
lgdp_exp	0.195***	0.038***	0.262***
	(15.79)	(3.8)	(22.85)
lexptime_exp	-0.109**	0.154***	-0.105**
	(2.64)	(4.4)	(2.80)
limptime_imp	-0.112**	0.071*	-0.109**
	(-3.02)	(2.2)	(3.17)
linst_imp	0.455***	0.614***	0.316**
	(3.63)	(6.1)	(2.79)
linst_exp	0.548***	0.916***	0.523***
	(4.11)	(8.28)	(4.31)
ltransinf_exp	-0.01	0.189	0.044
	(0.09)	(1.92)	(0.44)
ltransinf_imp	-0.159	0.157	0.214*
	(-1.44)	(1.59)	(2.1)
ldist	-0.326***	-0.152***	-0.408***
	(-11.80)	(-7.70)	(-16.19)
dlocked	-0.182***	-0.244***	-0.074
	(-4.08)	(-5.97)	(-1.79)
dcomlang_off	0.458***	0.084	0.509***
	(-7.35)	(1.86)	(9.29)
dcolony	-0.076	0.539***	0.073
	(-0.30)	(3.48)	(0.3)
dborder	0.338	-0.332***	0.389*
	(1.66)	(3.47)	(2.12)
dbilateral	0.679***	0.244***	0.784***
	(3.8)	(3.53)	(4.94)
lrel	0.046***	0.033***	0.050***
	(5.48)	(4.52)	(6.41)
_cons	3.604***	1.429***	3.672***
	(11.62)	(6.42)	(13.08)

Source: Author's calculation
Note: t-stats are reported in parenthesis

Table 12: Heckman without country dummies

	Total	Manufactures	Primary
ldist	-0.347*	-0.401*	-0.362***
	(-2.55)	(-2.30)	(-3.69)
dlocked	0.151	0.325	-0.382
	(0.55)	(0.88)	(1.94)
dborder	2.104**	3.384***	2.359***
	(3.15)	(4.12)	(4.98)
dbilateral	-0.524	-1.120*	-0.453
	(1.27)	(2.26)	(1.54)
dcomlang_off	-0.028	0.413	-0.146
	(-0.09)	(1.07)	(-0.65)
min_ltransinf	2.752***	2.456**	2.675***
	(4.34)	(3.2)	(5.8)
good_transinf	0.559	0.44	0.288
	(1.7)	(1.23)	(1.24)
max_ltransinf	2.254***	2.283**	0.481
	(3.73)	(2.73)	(1.08)
dssa	-1.741***	-2.651***	-1.078**
	(-3.72)	(-4.76)	(-3.24)
min_ltransinf2dssa	-1.829	-0.972	-3.112***
	(-1.55)	(-0.70)	(-3.66)
max_ltransinf2dssa	-1.659	-2.199	0.223
	(-1.74)	(-1.94)	-0.32
mills lambda	-10.698***	-12.233***	-7.561***
	(-14.86)	(-7.90)	(-20.05)
N	13243	11592	13243

Source: Author's calculation
Note: t-stats are reported in parenthesis

Table 13: Results of Africa only sample, 2005

	Total	Manufactures	Primary
ldist	-2.245***	-0.931**	-2.706***
	(-8.68)	(-3.27)	(-8.94)
dlocked	-3.949***	-0.876	-7.115***
	(-7.65)	(-1.57)	(-9.65)
dborder	2.032***	2.754***	2.379***
	(-3.9)	(-5.65)	(-4.4)
dbilateral	-0.158	-0.891	0.462
	(-0.24)	(-1.79)	(-0.67)
dcomlang_off	1.534***	0.188	1.662***
	(-5.9)	(-0.64)	(-5.9)
good_transinf	0.207	0.858	0.011
	(-0.42)	(-1.94)	(-0.02)
max_ltransinf	0.12	-3.379***	0.918
	(-0.11)	(-3.40)	(-0.77)
mills lambda	3.327***	-2.704	3.331***
N	2874	2149	2874

Source: Author's calculation
Notes: Min_ltransinf dropped due to collinearity
t-stats are reported in parenthesis

Table 14: Correlation of ltransinf_exp, lgdp03_exp and lpop03_exp

```
             | ltran~xp lgdp0~xp lexpd~xp lpop0~xp
-------------+------------------------------------
ltransinf~xp |   1.0000
  lgdp03_exp |   0.7304   1.0000
 lexpdoc_exp |   0.5361   0.4134   1.0000
  lpop03_exp |   0.1503   0.6266  -0.0482   1.0000
```

Source: Author's calculations

Table 15: Correlation of ltransinf_imp lgdp03_imp and lpop03_imp

```
             | ltran~mp lgdp0~mp lexpd~mp lpop0~mp
-------------+------------------------------------
ltransinf~mp |   1.0000
  lgdp03_imp |   0.7303   1.0000
 lexpdoc_imp |   0.5360   0.4134   1.0000
  lpop03_imp |   0.1503   0.6267  -0.0481   1.0000
```

Source: Author's calculations

Table 16: Results from first stage of adapted 2SLS, 2005

	ltransinf_exp	ltransinf_imp
lgdp03_exp	0.139***	
	(131.24)	
lexpdoc_exp	0.100***	
	(20.42)	
lpop03_exp	-0.092***	
	(-66.88)	
lgdp03_imp		0.139***
		-131.22
lexpdoc_imp		0.100***
		(20.39)
lpop03_imp		-0.092***
		(-66.90)
_cons	-0.295***	-0.295***
	(-92.00)	(-91.97)
r2	0.698	0.698
F	10556.014	10551.08
N	13688	13688

Source: Author's calculations

Note: t-stats are reported in parenthesis