Why Don't African Countries Trade More With Each Other? The Role of Border Crossings in General Equilibrium

Alexander Pearson *

UNC Chapel Hill

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Abstract

Despite geographical proximity and recent reductions in tariffs among African countries, there has been relatively little trade within Africa compared to its trade with other continents. This paper looks at recent improvements in border crossing and port efficiencies in Southern and Eastern Africa to estimate how such trade frictions affect trade flows. I use a general equilibrium gravity model with multiple sectors and trade with the rest of the world in order to capture both direct and indirect effects from border improvements. The reduction of border wait times from an average of 30 hours to 10 is estimated to have increased internal trade by 3.96 billion USD. This amounts to 21% of the total increase in trade between African countries between 2008 and 2014, with inland countries having a greater benefit. I further find an additional 9.46 billion USD increase in internal trade flows when I equalize border wait times to those seen in developed countries.

JEL Classification. F14, F15

Keywords: Africa, International Trade, Integration, Border Crossings, Gravity Model.

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1 Introduction

Although geographically close, countries in Sub-Saharan Africa (SSA) trade relatively little with one another. Intra-regional trade between countries in SSA amounts to 10% of total trade, much lower than other geographical areas.[1] Models that account for economic size, geographical distance along with other characteristics such as common language, colonial links and exchange rates, predict trade flows that would be higher than what are observed (World Bank 2009). Furthermore, the Linder Hypothesis (Linder 1961, Bernasconi 2013, Fajgelbaum et al. 2011), which states that countries with similar characteristics, usually measured in the literature by income distributions, will trade more with each other, seems not to apply to countries in SSA.

The low levels of inter-regional trade has not been due to a lack of attention. The benefits of integration, which allows countries to take advantage of economies of scale and to reallocate resources to more productive areas, have been advocated by African leaders and developmental agencies for several decades. This has led to the formation of 14 regional economic communities (RECs), of which each country is a member of at least one, with many countries being a member of several. These RECs have predominantly been focused on reducing the tariffs on goods between the member countries, but with mixed results (World Bank 2012). However, other characteristics of the region, such as poor transportation infrastructure and high non-tariff barriers, can also have a substantial negative impact on the trade flows between countries. For instance, in 2008, crossing the border from the Democratic Republic of Congo to Zambia took an average of 96 hours on top of having to drive on roads in poor condition and complete an average of 16 trade documents.

This paper studies this issue by investigating the impact of border frictions, primarily through border wait times, on bilateral trade flows and analyzes their significance to regional integration in a general equilibrium trade model. I focus

[1]To compare with other regions, intra regional trade as a fraction of total trade is 60% in Europe, 53% in Asia, 50% in North America, and 26% in South America.

my attention on two major RECs, the Southern African Development Community (SADC) and the East African Community (EAC), which significantly reduced their border wait times by enacting one-stop border posts (OSBP) between 2008 and 2014.

I use border survey data taken before and after the OSBP and combine this with various transportation cost variables such as the distribution and conditions of the road network, port efficiencies and product-specific tariff rates. I then analyze the effect of border wait times on bilateral trade flows in two steps. First, I estimate a reduced form gravity equation with importer-sector-year and exporter-sector-year fixed effects using a long difference specification between 2008 and 2014. Taking advantage of the multiple borders that some countries have to cross along their optimal transport route in order to trade, I use an identification strategy that relies on border crossings that are not controlled by the origin or destination country. This allows me to find the direct effects of border wait times on bilateral trade flows. By measuring the change in wait times, this analysis goes beyond the literature that estimates the effects of borders using a dummy variable approach. I find that a 10% wait time decrease for a border that trading partners do not control, yet still have to use, can increase trade between those partners by 3.36%. Furthermore, manufacturing and agricultural products saw the largest responses to border wait changes.

Changes in bilateral trade costs can also have important indirect effects on other countries. Therefore the second part of the paper uses a framework that incorporates these additional trade frictions into a general equilibrium gravity trade model developed by Allen et al. (2014) that includes multiple sectors. I calibrate the model using the time variation in the transportation costs and the corresponding trade flows for each trading pair. I then use a series of counterfactuals that show how intra-regional trade was affected by various improvements to border crossings and ports. For instance, to see how the recent OSBP improvements affected the share of trade between countries in the SADC and EAC, I provide a counterfactual where no border improvements occur. I find that overall trade would be 4.57 billion USD lower each year if the borders were not improved to 2014 levels. With an approximate cost of between 3.5 and 30 million USD, improving border crossing between countries offers a substantial return on investment.[2] Furthermore 87% of those gains were due to increases in trade within the region, suggesting that decreased border wait times spurred economic integration instead of increasing the proportion of foreign trade. I also consider counterfactuals that reduce border wait times to those seen in OECD (Organization for Economic Co-operation and Development) countries and improve port efficiencies to the level of the country with the most efficient ports, in terms of costs, which is China. These counterfactuals show that the increased port efficiency and the elimination of wait times at border crossings yield large benefits.

The paper is organized as follows. Section 2 provides a brief overview of the literature. Section 3 covers the relevant data used. Section 4 provides the empirical analysis using reduced form gravity equations. Section 5 describes the general equilibrium trade model, which is then calibrated, and section 6 provides counterfactual border friction scenarios. Section 7 offers conclusions. Further details on the model and additional results can be found in the online appendix.

2 Literature Review

The question of why African countries have such low trade with one another relates to a substantial literature on border effects and their relation to trade flows. The border effect puzzle came to attention with the seminal work of McCallum (1996), who found abnormally large estimates of borders effects of trade flows between the United States and Canadian provinces using a traditional gravity equation. This launched an array of studies that tried to explain these high estimates and provide a theoretical foundation to the border effect.[3] Anderson and van Wincoop (2003) pro-

[2]The Kazungula border, however, is estimated to cost 220 million USD due to needing a rail and road bridge constructed to substitute for the ferry operation, although construction has not started.

[3]These studies include different regions such as Europe (Nitsch (2000), Pisu and Braconier (2013) Reggiani et al (2014)), US and Japan (Parsley, Wei, 2001), and other regions between America and Canada (Coughlin and Novy (2011) and Gandhi and Duffy (2013) and also account-

vide an explanation for why the McCallum study found substantially overestimated border effects, stating that not accounting for multilateral resistance variables such as remoteness led to omitted variable bias.[4] Even accounting for remoteness, Anderson and van Wincoop (2003) still find sizable border effects between Canada and the United States. Analyzing border effects by looking at between and within country trade has the advantage of not requiring any information about the frictions that the border actually causes. However, the effect of this artificial border may have a variety of possible explanations as to why they inhibit trade such as differing regulations, border congestion, information frictions and heterogeneous substitution of goods. This creates difficulties in explaining how any particular aspect of borders actually affects trade flows between countries.

One way to solve this issue, as done in this paper, is to gather data on border characteristics that relate to transportation costs. In their paper on the six major puzzles of international trade, Obstfeld and Rogoff (2001) transportation costs as a dominant factor in why these puzzles remain unsolved. However, almost all the studies mentioned above use distance and tariffs to account for transportation costs. Although tariff reductions were the major contributor to increased international trade over the last half-century, tariffs have been reduced to negligible levels in many cases. Other costs to transport will thus be more significant in explaining the continuing border effect (Baier and Bergstrand 2001). Although this area of research is relatively untouched, a few papers do use other methods to measure transportation costs to account for the border effect. Gandhi and Duffy (2013) use the extra security measures on the Canadian-U.S border to explain the decline in trade share between the two countries. Pisu and Braconier (2013) look at the connectivity of road networks between European countries and see that higher connectivity within countries accounts for 25% of the reduction in trade among countries with borders them. Studies have also tried to apply this gravity equation approach to

ing for other variables (Hliberry (1999), Wei (1996), Frankel and Wei (1998), Anderson and van Wincoop (2003), Chen (2004), and Millimet and Osang (2007).

[4]Canadian provinces were estimated to trade 22 times more with other provinces than with the United States.

trade between African countries including Akpan (2014), who looks at the Economic Community of West African States (ECOWAS) and estimates a gravity equation using distance and percentage of roads paved to account for transportation costs.

Although the study of border effects has somewhat neglected transportation infrastructure in its empirical analysis, intra-country transportation infrastructure studies have been more prevalent. Chandra and Thompson (2000) and Michaels (2008) look at how U.S counties were affected by the building of highways that connected major cities from the 1950s onward. Banerjee et al. (2012) and Baum-Snow et al. (2013) have done similar analyses for China's road and rail development. Storeygard (2013) looks at the connections between hinterland cities in SSA and nearby major port cities and finds that the quality of connections affects the rural city's income, as measured by night time luminosity. Storeygard (2016) studies the impact of road improvements between 1960 and 2010 on city population growth. Other papers focus on the effect of infrastructure projects using structural models, such as the one developed by Eaton and Kortum (2002), to obtain general equilibrium impacts on welfare. Donaldson and Hornbeck (2014) look at how land values in 18th-century America changed with the creation of the railroad system. Donaldson (2015) similarly looks at colonial India to see how trade flows and welfare changed from the expansion of the railroad system. Alder (2017) estimated the welfare effects of the construction of India's Golden Quadrilateral Highway network using luminosity data. Allen and Arkolakis (2014) create a general equilibrium model that incorporates the topography of the country and determined that location accounts for at least 20% of the spatial variation in U.S incomes.

Finding data on the changes of non-tariff barriers that affect transportation costs can be difficult. Therefore, studies have also looked at the variation in prices of commodity goods due to changes in transportation infrastructure. Sotelo (2015) finds that an average farmer gains 16% in productivity and 4% in welfare due to the paving of existing dirt roads in Peru. Atkin and Donaldson 2014 provide a method of dealing with issues of using the price gap as a means of estimating trade costs and find that within-country trade costs due to log distances are four to five times higher in Ethiopia and Nigeria than they are in the United States.

3 Data

In order to capture transportation costs, I first create a transportation network that accounts for the quality of the roads between all countries in the SADC and EAC (16 countries in all). The main data sources are the Center for International Earth Science Information Network (CIESIN) and the African Development Bank Group, which provides details of the road networks in each country of the SADC and EAC for 2010. The data includes information on road types and conditions.

Since there have not been efficiency studies to determine the speeds for certain roads in these countries, I assign an approximated speed for each road given its type and condition. These approximations are calculated by taking roads of similar type and quality from data from the World Bank (2005) in India and Roberts et al (2010) in China. Therefore, I assume that a new paved highway that was in good condition had a speed of 70 km/h. For paved highways in poor or fair condition, a speed value of 40 km/h was assigned. Unpaved dirt or gravel roads have a speed of 25km/h assigned. Locations that did not have any transportation networks, I assign a speed of 10 km/h to account for potential small unobserved trails.

Next, I supplement this transportation network by incorporating border crossing frictions between all the countries. I use border specific survey data from 33 different crossings from the USAID, the World Bank and the African Development Bank. Each country has at least one border crossing survey. Each survey has, at a minimum, the wait time it takes to cross over to a specific neighboring country. If a neighboring pair does not have survey data for that crossing, an average of the wait times for each country's other border crossings was taken. Since many of the unreported borders are in low-traffic areas due to being far from large cities or main travel routes, I also conduct a robustness check in which the wait time for these unobserved border crossings is the average of low through-traffic crossings as reported by the World Bank (2010). Many border crossings took days to get across with the highest being five days on average. Other borders had very low wait times of a few hours. Many of the surveys also include monetary costs in fees that have to be paid to cross the border. In this transportation network I allow movement only through the official border crossings.

With this transportation network, I then begin to construct transportation costs from each country in my sample to the others. While a number of methods have been used to model transportation costs, Roberts et al. (2012) shows that travel times provide a suitable proxy for overall transport costs. In order to obtain transportation times in 2008 and 2014 from the constructed transport networks, I use a Dijkstra algorithm in ArcGIS to find the shortest travel time between each of the main cities of each country to every other main city in each country. To get the transportation costs to each country the location of the beginning and ending points are important. This is especially true if there are many large cities in one country that are all importing and exporting to other countries, leading to different travel costs for each city. To get around this issue, I take the top three to five cities in each country and find the travel costs to get to every other city in the other countries. Since cities may import or export more due to their relative size I use a weighted average of each city's travel costs weighted by their development in order to obtain a bilateral transportation cost measure.[5] For the main analysis in sections 4 and 5.3, I allow for the optimum route to change between 2008 and 2014 given the changes in border wait times. This leads to some trading partners having changes in their road transportation times even though there were no large changes in the road speeds during this time.[6]

Bilateral trade flow data was taken from UN Comtrade for the years 2008 and

[5]Since city-level measures of development are incomplete, I proxy for level of development by using the intensity of night time luminosity.

[6]For robustness I also include analysis for when I keep the routes identical in both time periods.

2014.[7] I use the two-digit product classification, leading to 97 different product types. I use import data since other studies have shown that import data is much more accurate compared to export data due to the fact that imports are more likely to be taxed. Some countries did not report trade flows in 2008. For these countries, I use the export data from other countries that did report in order to back out their imports. For trade with the rest of the world I combine countries into five groups: North America, 27 countries of the European Union, Asia, South America, and the rest of Africa. Table A24 shows the change in trade flows by sector and internal/foreign trade. We see that during this time, trade between other countries in the SADC and EAC saw significant gains compared to trade with foreign regions. This is especially true for the agriculture and manufacturing sectors. Indeed manufacturing goods traded internally accounted for nearly half of overall manufacturing trade in 2014.

Tariff data is obtained from two WTO databases, the Integrated Database and the Consolidated Tariff Schedules. The latter also states whether specific countries have certain trade agreements with each other. If no such trade agreement was listed, then the Most Favored Nations value was used. Incomes and Populations were taken from the World Bank Development Indicators. Distance was constructed the same way as travel times, i.e. taking the distance from the top cities in each country to the other cities in the other countries. Common language, whether the country is landlocked and adjacency are other variables that were used. Institutional variables such as rule of law, regulatory quality, political stability, and corruption were obtained from the Worldwide Governance Indicators.

[7] Additionally, I use IMF direction of trade (DOT) bilateral trade data to provide robustness checks.

3.1 Multi Modal Transportation

Several papers forgo the inclusion of interactions that are outside of the study area.[8] Others incorporate trade with the rest of the world such as Turner (2015), but assume sea trade to be constant during the period of analyses. Adding accurate rest-of-world trade and the corresponding costs have the potential to significantly change one's result. This is even more of a concern in this case study since 85% of total trade is with countries outside the study region.

The largest hurdle to incorporating different modes of transportation inside a general equilibrium model is the problem of providing a unit cost or ad valorem cost that is compatible with each mode. This practice is still in its infancy with no consensus on how it should be done. In southern and eastern Africa, road transportation is the predominant method of transportation, whereas sea trade is mostly used for trading with the rest of the world.[9] In order to include the transportation network with the rest of the world, costs pertaining to port usage needed to be acquired. To do this, I used the World Bank's Doing Business survey which surveys local freight forwarders, customs brokers, and traders in 189 countries. For each country, the survey breaks up the costs for both importing and exporting into domestic transport, border compliance, and documentary compliance. Each country is assumed to import a container of auto parts valued at 50,000 USD and weighing 15 metric tons. Exports are derived from each country's leading export.[10] It is also assumed that the cargo is shipped from the largest city within the respective country. Travel times and costs are also documented from the major city to the nearest border if the country is landlocked or the nearest port if not.

[8]Donaldson and Hornbeck (2014) allow for trade to take place over water but only to other areas in the U.S. Donaldson (2013) outlines four areas that can trade internationally within the Indian region for the particular good.

[9]Air transportation in Africa is also relatively common for trading with the rest of the world on the order of 10% (Hummels and Schaur 2013). I exclude this and railway transportation in order to simplify the analysis.

[10]These exclude goods such as diamonds and other precious metals; in these cases the second leading export is used.

The survey also includes data on the time and costs to go from the primary city to the port or border. This can give us an approximation of per-hour costs for road transportation. Section 4.2 goes over the strategy of combining different modes of transportation together. The monetary value of time, the additional costs at each port pair, and the tariff structure to the rest of the world gives most of the costs that are incurred in transporting goods across borders. One large unknown is the role that road-blocks and bribes play in each country. The data on transport cost to port or border may include these interactions but likely do not report the detailed structure of road block locations or the magnitude of charges at these road blocks. This however affects most studies concerning road transportation in developing countries and until reliable data is available and correctly incorporated into the transportation networks there is little to be done.

4 Empirical Analysis

In this section I estimate the effects of border wait times on trade flows using a reduced form gravity equation. Gravity equations have been used extensively to estimate a wide variety of determinants in trade.[11] Taking advantage of the border crossing surveys, I will be able to exploit the time variation to determine the effect of border improvements on trade flows. To account for any lag in the response of trade to changes in trade frictions, I conduct a long difference estimation with importer-product and exporter-product fixed effects between the period of 2008 and 2014 where all of the surveys and improvements were implemented. Let

$$\Delta \ln X_{ij}^{s} = \mu \Delta \ln T_{ij} + \beta_1 \Delta \mathbf{Z_{ij}} + \gamma_{\mathbf{is}} + \delta_{\mathbf{js}} + \epsilon_{\mathbf{ij}} \tag{1}$$

where X_{ij} are trade flows from i to j, T_{ij} is the sum of all border waiting times that i and j have to incur to trade with one another and $\mathbf{Z_{ij}}$ is the set of control variables including tariffs, road travel times and port efficiencies if one of the trading

[11] For a detailed overview see Head and Meyer (2010)

partner is overseas.[12]

The importer-sector and exporter-sector fixed effects γ_{is} and δ_{js} account for the unobservables that are determinants to trade flows such as productivity, labor and capital prices and institutions. This method also absorbs variables that we observe but that are time and country specific, such as income.[13]

Ideally the changes in border crossing wait times would come from events that were exogenous to countries decision to trade with one another. In practice, this may not be true. If two countries expected to trade more with each other in the future, this may lead them to improve their border crossings to allow an easier movement of goods. In this scenario, the goods might have been moved regardless, and the improved border crossings could have little effect and would lead to an upward bias in the estimate for μ. The opposite may also be true. For example, when consumers and firms in each country wish to trade with one another, it may lead to higher protectionist measures from their governments. However, a key characteristic of having many countries in the same region is that, when one country decides to change their border frictions with their neighbor, regardless of their intent, other countries that use the border crossing to get to their other trading partners, now have an exogenous change in their transportation costs. This is due to other countries having very little influence on how the first two countries' improve their transportation network. The more thorough approach that I apply here is to use a border or a set of borders in between two non-adjacent trading partners i and j, as an instrument for the total time cost between the respective trading partners. This subset of border/borders will be correlated to the overall time cost but exogenous to i and j's unobserved actions to increase trade with one another. Furthermore, these non-adjacent countries account for only 1% of the trade going through such that there is no reverse causality from

[12]Section 4.2 goes over the case in which the independent variable T is the aggregate transportation friction from roads, ports and border wait times with various robustness checks.

[13]This will partially limit the analysis by restricting the ability to look at other country time specific variables that may be of interest such as corruption levels, the rule of law and other governance variables that will be absorbed into importer and exporter year fixed effects.

trade to waiting times since they have little effect on the congestion at these borders.

I therefore use a two-stage least squares estimate with the first stage defined as

$$\Delta \ln T_{ij} = \alpha_1 \Delta \ln B_c + \psi_i + \phi_j + \nu_{ij} \tag{2}$$

Where $c \in \Omega_{ij}$ and Ω_{ij} is the set of borders that i and j have to go through to trade with each other and ψ_i and ϕ_j are the importer and exporter fixed effects. Then we can use this to estimate the main equation by

$$\Delta X^s_{ij} = \beta_1(\hat{\alpha_1} \Delta \ln B_c) + \Delta \mathbf{Z_{ij}} + \gamma_{\mathbf{is}} + \delta_{\mathbf{js}} + \epsilon_{\mathbf{ij}} \tag{3}$$

where $\hat{\alpha_1} \Delta \ln B_c = \Delta \ln \hat{T}_{ij}$ is the predicted values from (2).

Using an instrumental variable that only accounts for 1-2% of the total trade within the region raises potential concerns. First the types of goods traded may be very different from the overall population of trade flows. However, as we can see in Table A1, the proportions of traded goods among sectors are relatively similar to non-adjacent trade.

Another potential concern is the endogeneity of trade flows to border times due to congestion. All else equal, an increase in trade flows between two countries would increase the traffic and the number of trucks that would have to wait in line to go through the border resulting in longer wait times. This would lead to the wrong conclusion that higher wait times leads to higher volumes of trade. To check for reverse causality, I look at the effects of trade flows on border wait times by creating a measure for trade flows that is independent of policy decisions and investment made during that time period. This can be found in appendix B.1. However as mentioned before, when limiting my sample to non-adjacent countries, this endogenous effect would be mitigated, since they account for only 1% of what is traded on the studied transportation network. Therefore, any changes in trade flows between these countries will have a marginal effect on overall wait times.

There has been a growing literature on the consequences of performing OLS on logged functions which increases the likelihood of a heteroskedastic error term. Silva and Tenreyro (2006) show that this can be accounted for by using other estimation techniques such as the Pseudo Poisson Maximum Likelihood estimator. Not only do such alternatives account for the heteroscedasticity in the error term but they allow one to account for zeros in trade flow data where they would otherwise have been thrown out.

One important characteristics of this study is the quasi-random nature with which trading partners receive their trade frictions through border wait times due to their lack of control over non-adjacent borders. However, if changes in border wait times are highly correlated between borders, it would suggest that there are non-observables that could affect both border wait times and trading behavior among countries, leading to biased estimates on border wait times. To check for this, I run an unbalanced panel regression of the change in the border wait time of one of the trading partner's own borders, on the average time change of borders not controlled by either trading partner along their trade route. Since each country belongs to many trade routes I also control for this by using country fixed effects. Table A3 shows close to zero correlation between borders controlled by trading partners and borders not controlled along their trade routes with a t score of -.03.

Estimating equation 1 assumes that each product traded will be affected equally by border wait times. However, a more likely scenario is that some products, such as agricultural goods, will be affected differently than other goods such as copper which may not be as time sensitive. To see how trade costs are affected in a per sector basis, I estimate

$$\Delta \ln X_{ij}^{s} = \mu^{s} \Delta \ln T_{ij} + \beta_1 \Delta \mathbf{Z}_{\mathbf{ij}}^{\mathbf{s}} + \gamma_{\mathbf{i}}^{\mathbf{s}} + \delta_{\mathbf{j}}^{\mathbf{s}} + \epsilon_{\mathbf{ij}}^{\mathbf{s}} \tag{4}$$

where s now denotes the type of industry the traded good comes from. As mentioned in section 3, the trade flow data is categorized by 97 products that can be aggregated into 15 sectors, which I did in order to make the importer-sector-year and exporter-sector-year fixed effect matrices small enough to be computationally feasible.[14]

4.1 Gravity Equation Estimation Results

To see how border wait times affect trade flows following the specification in equation 1, I begin with the 15 sector case excluding the rest of the world. This baseline result is illustrated in Table 1. Columns 1 to 3 show both adjacent and non-adjacent trading partners with column 3 including the full specification. As we see, a 10% decrease in border wait times is expected to increase trade flows by 3.64%. However, when taking into account the proximity of trading partners using distance, the effects of border wait times are smaller when partners are farther away. That is, the trading partners that were farther than the median distance away from each other saw only a 1.2% increase in trade for every 10% decrease in border wait times. This may be due to information frictions that make it more difficult for distant countries to take advantage of lower trade barriers. When I disregard trade between adjacent countries within the study region there is still a statistically significant negative relationship although with a lower magnitude which is consistent with the findings in column 3 since, by construction, non-adjacent countries are farther away.

[14] Found at http://www.foreign-trade.com/reference/hscode.htm

Table 1: Growth of trade flows from infrastructure changes: No rest of world trade

	(1)	(2)	(3)	(4)	(5)	(6)
Change in Border Wait Times (log)	-0.184*	-0.364***	-0.898***	-0.161*	-0.189**	-0.394***
	(-1.71)	(-3.42)	(-6.97)	(-1.75)	(-2.00)	(-2.99)
Change in Drive Times		0.00229***	0.00183***		0.000299	0.000277
		(12.29)	(8.31)		(1.24)	(1.00)
AboveAvgDist Interaction			0.778***			0.237*
			(5.94)			(1.76)
Change in Tariffs			0.456***			0.531***
			(8.76)			(10.78)
Number of Documents			-0.461			-0.154
			(-1.41)			(-0.49)
Adjacency/Non Adjacency	Both	Both	Both	Non adjacent	Non adjacent	Non adjacent
N	3360	3360	3330	2505	2505	2490
R^2	0.210	0.250	0.277	0.276	0.277	0.317

The dependent variable is growth in imports from 2008 to 2014 aggregated to 15 different sectors. Regressions are controlled for importer-year-sector and exporter-year-sector fixed effects with robust standard errors. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A4 incorporates trade with the rest of the world and includes a control for port costs.[15] Changes in border wait times show similar effects when looking at southern and eastern African trading partners and trade that occurs with the rest of the world. Changes in port costs during this time period correlated positively with trade flows. A potential reason could be that higher trade volumes put larger demands on ports than they have capacity for, which could raise costs.

To further identify the effects of border wait times on trade flows, Table 2 uses borders not operated by the trading partners (but that they still have to pass through) as an instrument to control for the possibility of wait times endogenously being reduced from expected trade flows. We see that changes in wait times due to non-adjacent borders has larger effects on trade flows amounting to an increase of 4.57% in trade flows due to a 10% decrease in wait times. To see if an instrumental variable approach is needed, I conduct a Durbin test and obtain a value of

[15] Additional tables can be found in the Web Appendix.

4.44, which rejects the null hypothesis that the variables in the OLS regression alone are exogenous and shows it as correct to treat border wait times as an endogenous variable. In checking for weak instruments, I find an F-statistic of 697.67, with a threshold of 16.38 meaning I can reject the null hypothesis that the instrument is weak.

Table 2: Growth of trade flows from infrastructure changes: Instrumental variable approach

	(1)	(2)	(3)	(4)
Change in Border Wait Times (log)	-0.332**	-0.442*	-0.457*	-0.457*
	(-2.12)	(-1.87)	(-1.95)	(-1.95)
Change in Drive Times	0.00206**	0.00193**	0.00186*	0.00186*
	(2.25)	(2.03)	(1.96)	(1.96)
AboveAvgDist Interaction		0.224	0.231	0.231
		(1.02)	(1.05)	(1.05)
Change in Tariffs			0.111***	0.111***
			(3.06)	(3.06)
Number of Documents				1.062
				(1.19)
N	1246	1246	1246	1246
AR^2	0.446	0.446	0.450	0.450
IV Results for Specification (4)				
Durbin score			4.44	p = 0.0351
Wu-Hausman			2.7781	p = 0.0959
First Stage F-stat			697.677	
First Stage Partial AR^2			0.473	

The dependent variable is growth in imports from 2008 to 2014 aggregated to 15 different sectors. Regressions are controlled for importer-sector and exporter-sector fixed effects. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Tables A6, A7 and A8 show estimates for equation 4, which allows for the elasticity of trade flows due to border wait times to be different for each sector. Most sectors have been responsive to the changes in border wait times. These tables show mostly the expected patterns, namely that sectors that we expect to be more time sensitive have larger estimates. The sector of chemicals, leather, hide products, footwear/headgear and metals were not statistically significant. These products may be less time sensitive than agricultural products, which saw the largest sensitivity to changes in border wait times. This can be seen in Table A9, which shows the results of organizing trade into the three sectors of agriculture, manufacturing and resource extraction. Although agricultural goods have the highest elasticity with respect to border wait times when trading partners are close in proximity, the coefficient becomes virtually zero when dealing with trading partners that are above the median in terms of distance. This can be expected as most agricultural products have a short time window before they perish. Resource extraction products saw the lowest response to changes in border wait times. Manufacturing products saw not only an 8% increase in trade flows due to a 10% decrease in border wait times when trading partners were below median distance apart, but also a 1.96% increase for trading partners that were above median distance from each other.

4.1.1 Pseudo Poisson Maximum Likelihood Estimator

As mentioned above, the Pseudo Poisson Maximum Likelihood estimator can provide additional insight into the effects of transportation frictions, such as border wait times, on trade flows. Table 3 shows the estimates when excluding trade with the rest of the world. The coefficient for the estimate of border wait times are relatively similar to the estimates obtained when OLS with fixed effects was implemented. One large difference is that the R-squared is higher for the PPML estimation than for the OLS with fixed effects which could be due in part to the advantage of allowing zero values within the estimation. One issue that arose in using OLS estimates was that tariff rates were positively correlated with trade flows. Allowing for zero trade flows results in the estimates for tariffs having a statistically significant negative sign as we would expect.

Table 3: Growth of trade flows from infrastructure changes using Pseudo Poisson Maximum Likelihood estimation

	(1)	(2)	(3)	(4)	(5)	(6)
Border Wait Time (log)	-0.444***	-0.265**	-0.371***	-0.603***	-0.431***	-0.499***
	(-7.05)	(-2.38)	(-3.14)	(-4.19)	(-3.53)	(-3.55)
DriveTime (log)		-0.0386	0.270	0.297	0.294	0.269
		(-0.21)	(1.22)	(0.85)	(1.29)	(0.81)
Tariffs (log)		-0.126***	-0.108***	-0.0360	-0.0964***	-0.0740**
		(-4.45)	(-3.58)	(-0.99)	(-3.11)	(-2.00)
Border-Distance Interaction			-0.0967**	-0.105**	-0.0741*	-0.105**
			(-2.18)	(-2.11)	(-1.72)	(-2.06)
Sectors	All	All	All	Ag	Manf	Res
N	3874	2744	2744	1681	2105	1764
R^2	0.910	0.942	0.943	0.947	0.936	0.946

The dependent variable is growth in imports from 2008 to 2014 aggregated to 15 different sectors. All variables are calculated by a 3 year average. Regressions are controlled for importer-year-sector and exporter-year-sector fixed effects. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

4.2 Aggregated Transport

Another method used in this paper is to create a transportation friction measure that incorporates the changes in driving costs, border wait time costs and port costs. One benefit of this method is that it reduces the number of parameters needed to calibrate the general equilibrium trade model. An additional benefit comes from being able to analyze multiple modes of transportation using monetary values. Converting border and road friction measures into a monetary value however, requires information on the cost of time in transit. Two different strategies are used in this paper to create this transportation cost measure as explained below. It is important to note that increasing the monetary value of the wait time is equivalent to increasing the weight of the importance of overall change in aggregate transportation costs.

4.2.1 Ad-Valorem Time Costs

One method for getting the ad valorem time costs is to use estimates from studies that measures the cost of delays during transit. For instance, Hummels and Schaur 2013 estimate an equivalent .6 to 2.1% ad-valorem tariff for every additional day in transit. When using a standard 20 foot container valued at 50,000 USD, we would expect costs to be between 300 USD and 1050 USD per day. For border crossings it will be assumed that waiting 24 hours at a border is the same as a full day since the time was still counted for overnight stays. Therefore, each hour would cost between 43.75 and 12.5 USD. Table A12 converts each hour of waiting into 43.75 USD and Table A13 into 12.5 USD. Columns 4 and 5 in both tables again use non-adjacent borders as an instrument for the aggregate trade cost measure. We see that changes in the value assigned to each hour of waiting does not significantly change the coefficient of interest. I find that a 1% decrease in the cost of transportation between trading partners leads to a 1.16% increase in trade.

4.2.2 Trucking Survey Costs Strategy

Another method for obtaining ad valorem costs would be to use the World Bank Doing Business survey which includes the time and costs required to go from the primary city to the port or border. This can give us an approximation of per hour costs for road transportation which I can then use to get the average marginal cost of an additional hour of driving. Table A30 shows that every hour adds on average an additional 27 USD to transport costs, which is approximately the midpoint of the ad-valorem tariff estimates found by Hummels and Schaur 2013. Table A10 shows similar magnitudes to those found in Table A12 and Table A13 which were derived from the ad valorem estimate.

4.3 Robustness Exercises

4.3.1 Optimal Routes

One assumption made when constructing border wait time measures between bilateral trading partners is that the optimal path is allowed to change given new border times between the countries. To check whether this assumption will affect my results, I re-estimate Table 1 but hold constant the route used for travel. Table A15 shows the new results and Table A11 uses the aggregated transport friction measure holding the optimal route constant. In both instances the border friction measure remains negative and close to what is found when allowing the route to change. This is most likely due to the fact that many routes used in 2008 were still the optimal routes in 2014.

4.3.2 Symmetric versus Non-Symmetric Border Crossings

Although not all surveys reported times disaggregated to each direction, a large portion of them did. It is assumed that if only one time was given for the border wait time it represented the average of both directions. Therefore, I provide analysis both assuming that border wait times are symmetric, in which case I take the average of each direction, and where the border wait times are non-symmetric, to the extent in which the data is available. Table A16 reports the estimates to the specifications made in Table 1 but assumes that borders are symmetric. Point estimates stay close to the main estimates which is not surprising as border wait times for each direction are similar.

4.3.3 Trade Flow Measures

When import data was not available between two trading partners but export data was available from the other reporter, I assume that the amount of trade that occurred was equal to the export data of the other reporter. Table A18 uses data only for imports and records zero even if the respective trading partner's export data contradicts the import data. Table A19 exclusively uses export data. Since more zero data is recorded, Table A20 uses the PPML estimator with import data exclusively which allows for zero trade flows. Table A17 then takes the average of the importer's data and the exporter's data with little change in the estimates. I assume that goods are traded by road or by sea. However, 10% of African trade also takes place by air (Hummels and Schaur 2013). To account for this, I re-estimate the reduced form model but exclude products that are more likely to be transported by air.[16]

4.3.4 Institutions

To analyze the effects that institutional characteristics have on how trade reacts to travel costs, I include interaction effects for four different variables; regulation quality, rule of law, political corruption, and political stability. Table A21 shows that better regulatory quality, rule of law, political stability and less corruption increases the amount of trade between partners when travel costs are decreased.

4.4 Limits to Reduced Form Gravity Equations

Although the fixed effects gravity estimator is one of the most common methods for estimating gravity equations there remains one main limitation. Estimates of the border wait time variables only show the direct effects on trade and do not take into account potential trade dispersion. The fixed effects gravity estimator is able to control for this multilateral resistance term but cannot estimate the indirect effects of changes in trade frictions on trade flows. This is a concern when conducting counterfactuals since the trade between two trading partners not only depends on the changes in transport frictions between themselves, but also of other trading partners. In the following section, I therefore use a general equilibrium trade model in order to undertake counterfactuals.

[16]These product groups include flowers and other plants, fruits and vegetables, pharmaceuticals, essential oils and perfumes, cinematographics, mechanical appliances/parts, foot and headgear/parts, medical/surgical equipment, and works of art.

5 General Equilibrium Framework

A large number of microfounded general equilibrium trade models provide gravity equations for trade flows. The first was the Armington model with intermediate inputs first used by Anderson (1979). Krugman (1980) derived a gravity equation using monopolistic competition and homogeneous firms and intermediate inputs while Meltiz (2003) used heterogeneous firms. Eaton and Kortum (2003) used a Ricardian perfect competition model. Several other papers have extended these workhorse models, But these models face difficulties in guaranteeing uniqueness and characterizing comparative statics, often using sub optimal assumptions to attempt both. Allen, Arkolakis and Takahashi (2014) provide a universal gravity model that nests these other models and allows for uniqueness in equilibrium and closed form comparative statics with minimal assumptions.

5.1 Model Setup

In this section I define a general equilibrium trade model created by Allen et al (2014) allowing for multiple sectors.[17]

5.1.1 Multi-Sector Model

Let the world be comprised of a set $S \in (1, \ldots, N)$ of locations. These locations can either be countries or smaller administrative areas. For each location, Y_i denotes the gross income and X_{ij} the value of location j's imports from location i. Trading between the locations is hampered by a corresponding trade friction represented by $K_{ij} > 0$. This represents the costs associated with trading between the two locations, such as distance, time, and tariffs.

I include multiple sectors as non- tariff barriers and poor infrastructure may affect traded goods differently . For instance, large wait times at each border may

[17] Appendix A.1 provides a full description of the single sector model along with comparative statics. These can also be found in Allen et al. (2014).

make it difficult to transport a variety of agricultural goods due to spoilage. Similarly, manufactured goods may need a variety of complex machines which requires the speedy imports of crucial parts to prevent production disruptions due to broken parts. Waiting weeks instead of days for these items may make it difficult to even set up manufacturing in the first place. To account for this I extend the gravity model to include three sectors, agriculture, manufacturing and resource extraction. Again, using work done by Allen et al. (2014) let $s \in \{M, A, R\}$ be the set of sectors.

Next, I define, as in Allen et al (2014), (γ_i) and (δ_j) as the exporting and importing capacity respectively; this accounts for the microfounded characteristics found in modern trade models, such as wages, prices, productivities, and labor endowments. These two variables are solved endogenously within the general equilibrium model, allowing us to make fewer assumptions of the underlying mechanisms that many of the seminal trade models focus on while still providing the same outcome. Allen et al (2014) show that four conditions, described below, must be met in this framework in order to obtain the general equilibrium outcomes found in many of the current workhorse trade models.

Condition 1: For any country $i \in S$ and $j \in S$, the value of aggregate bilateral trade flows is given by

$$X_{ij}^s = K_{ij}^s(\gamma_i)(\delta_j^s). \tag{5}$$

Here, the importer shifters are equalized through each sector. This would be the case if there were no frictions in the labor market in country i, which is assumed here. K_{ij}^s is interpreted as sector specific trade frictions letting different commodities have different costs for transport.

The next two conditions are concerned with assumptions of goods market clearing and trade balance that are made in almost all trade models. Specifically,

Condition 2: For any location $i \in S$

$$\sum_j X^s_{j,i} = B^s_i Y_i. \tag{6}$$

That is, the total sum of all purchases from all locations, including its own location, is equal to their income share for that sector for all locations. Next, we have

Condition 3: For any location $i \in S$

$$\sum_s \sum_j X^s_{i,j} = Y_i. \tag{7}$$

That is all exports, including the "exports" to their own location, must equal to their income. Although common in the trade literature, this condition rarely holds for countries. Allen et al (2014) addresses this concern and provides a strategy to account for unbalanced trade that will be included in estimation and the counterfactual analysis.

The universal gravity model also assumes a log-linear parametric relationship between gross income and the exporting and importing shifters:

Condition 4: For any location $i \in S$

$$Y_i = B_i \gamma_i^\alpha \left(\prod_s (\delta^s_i)^{\theta^s} \right)^\beta \tag{8}$$

where $\alpha \in \mathbb{R}$, $\beta \in \mathbb{R}$ $\theta^s \in \mathbb{R}$ are the gravity constants and $B_i > 0$ is an (exogenous) location specific shifter. These gravity constants control the response income has on the importing and exporting shifters. In section 5.2, I estimate (α, β, and θ^s) to allow for the analysis of counterfactual scenarios.

The last condition pins down the equilibrium trade flows by normalizing gross incomes, taking advantage of Walras's law. Finally,

Condition 5: World income equals to one

$$\sum_i Y_i = 1. \tag{9}$$

5.1.2 Multi-Sector Comparative Statics

To see how trade frictions affect trade flows and welfare in the model, I take advantage of the work done by Allen et al (2014) who derive comparative statics for the importer and exporter shifters. It is easy then to show the general equilibrium effects for trade and welfare at any location given a change in bilateral trade frictions between any two locations.

The addition of multiple sectors follows the same method as the single sector case above.[18] The appendix describes the construction of the multi sector comparative statics in detail. It is now possible to have a change in transportation frictions in a specific sector between two countries affect trade between any other country pair and sector. Specifically:

$$\frac{\partial \gamma_l}{\partial K_{ij}^s} = X_{ij}^s (A_{l,i}^+ + A_{l,N+j}^+) - c_{ij}^s$$

and

$$\frac{\partial \delta_l^{s'}}{\partial K_{ij}^s} = X_{ij}^s (A_{(s'N+l),i}^+ + A_{(s'N+l),N+j}^+) - c_{ij}^s$$

where A^+ is a $(N + SN) \times 2N$ matrix and the Moore pseudo inverse to the matrix

$$A = \begin{pmatrix} (\alpha-1)Y & \beta\theta_1 Y - X^1 & \dots & \beta\theta_s Y - X^s \\ \alpha Y - X^T & \beta\theta_1 Y - E^1 & \dots & \beta\theta_s Y - E^s \end{pmatrix}$$

where Y is a $N \times N$ diagonal matrix whose i^{th} diagonal is equal to Y_i, E^s is a $N \times N$ diagonal matrix who's i^{th} diagonal is equal to

[18] The construction of the comparative statics for the single sector model can be found in the online appendix of Allen et al. (2014)

$$E_i^s = \sum_j K_{ji}^s \exp\{y_j\} \exp\{z_i\}$$

or location i's total expenditure on goods in sector s. X and X^s are the total and sector specific $N \times N$ trade matrices respectively. Again, c_{ij}^s pins these values down due to our assumption of condition 5 which states that world income equals one.[19]

Therefore the effect of a change in transportation frictions for sector s between countries i and j on trade of sector $s^{'}$ from k to l is:

$$\frac{\partial \ln \hat{X}_{kl}^{s^{'}}}{\partial \ln \hat{K}_{ij}^s} = \frac{\partial ln\gamma_j}{\partial ln K_{ij}^s} + \frac{\partial ln\delta_k^{s^{'}}}{\partial \ln K_{ij}^s}$$
$$= X_{ij}^s(A_{l,i}^+ + A_{l,N+j}^+) + (A_{(s^{'}N+l),i}^+ + A_{(s^{'}N+l),N+j}^+)) - 2c_{ij}^s$$

and income changes for country l is defined by.

$$\frac{\partial ln Y_l}{\partial ln K_{ij}^s} = \alpha \frac{\partial ln\gamma_l}{\partial ln K_{ij}^s} + \beta \sum_{s^{'}} \theta^{s^{'}} \frac{\partial ln\delta_l^{s^{'}}}{\partial ln K_{ij}^s} =$$
$$X_{ij} \times (\alpha(A_{l,i}^+ + A_{N+l,j}^+ + c_{ij}^s) + \beta \sum_{s^{'}} \theta^{s^{'}} (A_{(s^{'}N+l),i}^+ + A_{(s^{'}N+l),N+j}^+ + c_{ij}^s)$$

5.2 Model Estimation

Section 5.1 described a model in which for any given α, β, θ_s, income shifters B_i^s and trade frictions K_{ijt}^s, a unique general equilibrium could be solved by a set of endogenous import and exporter shifters. This subsection will address the estimation of α, β and a trade cost parameter μ using the trade flow and travel time data, which

[19] Specifically:

$$c_{ij}^s \equiv \frac{1}{Y^W(\alpha + \beta \sum_{s^{'}} \theta_{s^{'}})} X_{ij}^s \sum_l Y_l(\alpha(A_{l,i}^+ + A_{l,N+j}^+) + \sum_{s^{'}} \beta(A_{(s^{'}N+l),i}^+ + A_{(s^{'}N+l),N+j}^+))$$

allows for the opportunity of counterfactuals and welfare analysis in section 6. I use the method in Allen et al (2014) which takes advantage of the general equilibrium structure of the model. The approach calculates the importer and exporter shifters directly from the model and predicts the corresponding trade flows. It then estimates the gravity constants and trade cost parameter μ by taking the least squared errors between the observed change in trade costs and the predicted change.

$$(\alpha^*, \beta^*, \theta_1^*, \dots, \theta_s^*, \mu^{1*}, \dots, \mu^{s*}) = arg \min_{\alpha,\beta \in \mathbb{R}, \mu \in \mathbb{R}^S}$$
$$\sum_s \sum_i \sum_j \left(\ln \hat{X}_{ij}^{s\ observed} - \ln \hat{X}_{ij}^{s\ predicted} \right)^2. \tag{10}$$

As in Allen et al (2014) the method used to calibrate $(\alpha^*, \beta^*, \theta_1^*, \dots, \theta_s^*, \mu^{1*}, \dots, \mu^{s*})$ is through a grid search. A computationally intensive strategy would be to solve the model to obtain $\hat{X}_{ij}^{s\ predicted}$ for each iteration. To simplify the estimation procedure, I follow Allen et al (2014) and take first order approximations to both $\ln \hat{\gamma}_i$ and $\ln \hat{\delta}_j^s$ such that

$$(\alpha^*, \beta^*, \theta_1^*, \dots, \theta_s^*, \mu^{1*}, \dots, \mu^{s*}) = arg \min_{\alpha,\beta \in \mathbb{R}, \mu \in \mathbb{R}^S}$$
$$\sum_s \sum_i \sum_j \left(\ln \hat{X}_{ij}^{s\ o} - \hat{T'}_{ij}^{s} \mu - \ln \hat{\gamma}_i \big(\hat{T}\mu; \alpha, \beta, \theta\big) - \sum_s \ln \hat{\delta^s}_j \big(\hat{T}\mu; \alpha, \beta, \theta\big) \right)^2 \tag{11}$$

where

$$\ln \hat{\delta^s}_j \big(\hat{T}\mu\big) \approx \sum_{s'} \sum_k \sum_l \frac{\partial \ln \hat{\delta}_j^s}{\partial \ln \hat{K}_{kl}^{s'}} \hat{T}_{kl}^s \mu^s \tag{12}$$

and

$$\ln \hat{\gamma}_i \big(\hat{T}\mu\big) \approx \sum_{s'} \sum_k \sum_l \frac{\partial \ln \hat{\gamma}_i}{\partial \ln \hat{K}_{kl}^{s'}} \hat{T}_{kl}^s \mu^s. \tag{13}$$

I calibrate the set of parameters in two steps. First, I estimate the set of optimal trade parameters μ^{s*}. It can be shown that equation 11 can be written as

$$\mu(\alpha, \beta, \theta_1, \ldots, \theta_s) =$$

$$\left(\left(\boldsymbol{D}(\alpha, \beta)\hat{\boldsymbol{T}}\right)' \left((\boldsymbol{D}(\alpha, \beta)\hat{\boldsymbol{T}}\right) \right)^{-1} \left(\boldsymbol{D}(\alpha, \beta)\hat{\boldsymbol{T}}\right)' \hat{\boldsymbol{y}} \tag{14}$$

where $\hat{\boldsymbol{T}}$ denotes a $SN^2 \times M$ vector whose $\langle i + j(N-1) \rangle$ is the $1 \times M$ vector $\hat{T'}^s_{ij}$, $\boldsymbol{D}(\alpha, \beta)$ is the $SN^2 \times N^2$ matrix with $\langle i + j(N-1), k + l(N-1) \rangle$ representing $\frac{\partial ln X^s_{ij}}{\partial K^s_{kl}}$, and $\hat{\boldsymbol{y}}$ denotes the $N^2 \times 1$ vector whose $\langle i + j(N-1) \rangle$ row is $ln \hat{X}^{s\,o}_{ij}$.

Therefore for any $\alpha, \beta, \theta_1, \ldots, \theta_s$, μ^s can be estimated using ordinary least squares on the general equilibrium transformed explanatory variable $\hat{T^s}^{GE}_{ij}$:

$$\ln \hat{X}^s_{ij} = (\hat{T^s}^{GE}_{ij})' \mu^s + \epsilon^s_{ij} \tag{15}$$

where

$$\hat{T^s}^{GE}_{ij} = \sum_{s'} \sum_{k} \sum_{l} \frac{\partial \ln \hat{X}^s_{ij}}{\partial \ln \hat{K}^{s'}_{kl}} \hat{T}^s_{kl}$$

and

$$\frac{\partial \ln \hat{X}^{s'}_{ij}}{\partial \ln \hat{K}^s_{kl}} = \frac{\partial ln \gamma_i}{\partial ln K^s_{kl}} + \frac{\partial ln \delta^{s'}_j}{\partial \ln K^s_{kl}}$$

The second step is to find the gravity constants $\alpha, \beta, \theta_1, \ldots, \theta_s$ which minimize the total squared errors. As shown in Allen et al. (2014) this can be written as

$$(\alpha^*, \beta^*, \theta^*_1, \ldots, \theta^*_s) =$$

$$arg \min_{\alpha, \beta \in \mathbb{R}} \hat{\boldsymbol{y}} \left(\boldsymbol{I} - \hat{\boldsymbol{T}} \left(\left(\boldsymbol{D}(\alpha, \beta)\hat{\boldsymbol{T}}\right)' \left((\boldsymbol{D}(\alpha, \beta)\hat{\boldsymbol{T}}\right) \right)^{-1} \left(\boldsymbol{D}(\alpha, \beta)\hat{\boldsymbol{T}}\right)' \right) \hat{\boldsymbol{y}}. \tag{16}$$

Using a three-sector version requires solving five parameters. I perform a grid search to limit the control space then, taking the set of parameters, perform a random search around those values to calibrate the parameters.

This method does use approximations to the fully solved model approach in order to obtain the calibrated parameters. Appendix B.2 compares both methods using Monte Carlo simulations and finds that the approximation approach provides similar results to the fully solved model approach but in a fraction of the time.

5.3 General Equilibrium Calibration Estimation Results

Table 4 shows the results for equation 15 done with various gravity constants of alpha and beta. Row 1 shows estimates when minimizing equation 14 from section 5.2 which results in $\alpha = -23.00$ and $\beta = -1.40$. By construction the R squared will be the largest among the comparisons. However, the calibrated values for alpha and beta were able to explain more of the data than calibrated results in similar exercises in Allen et al. (2014) which maximized the gravity constants with an R-squared of 0.0234. It is also useful to note that although the GE estimation results in a lower R squared than the fixed effects estimation, the GE estimation is only using one covariate rather than over 40 for the fixed effects estimation. The coefficient indicates that for a 1% reduction in trade frictions, both directly from a country having lower transport costs or indirectly from other countries having higher transport costs to their partners, results in a .62% increase in trade flows with high statistical significance. Row 2 shows the alpha and beta values calibrated from Allen et al. (2014). Row 3 are values found in Eaton and Kortum (2002) when the trade elasticity value is converted a value that corresponds with the universal gravity model, and Row 4 shows values found in Alvarez and Lucas (2007). The explanatory power in values found in other papers appears to be low when applied to the SADC and EAC. This may be due to developing countries reacting differently to transportation changes than developed countries,from where these other gravity constants were estimated.

Table 4: GE single sector results

Type	alpha	beta	μ	StdEr	R^2
Own Calibration	-23.00	-1.40	-0.62	0.0154	0.0819
AAT Calibration	-30.20	-27.90	-2.36	0.4454	0.0089
EK	-3.85	-3.04	-0.10	0.0790	0.0001
AL	-0.67	-0.33	-5.76	3.3252	0.0008

Coefficients represents the estimated coefficient of the general equilibrium estimation. AAT-Calib represents the alpha and beta values calibrated from Allen et al (2014), EK are values found in Eaton and Kortum (2002) and AL are values found in Alvarez and Lucas (2007).

When looking at a three-sector case and using the calibrated values for α and β found in the single sector model, we see in Table A22 that large gains in the explanatory power of the data in the manufacturing sector but less in agriculture and resource extraction. All three sectors have negative and significant coefficients with manufacturing being of the largest magnitude. Figure 2 shows the R-squared values of the general equilibrium estimation over combinations of different parameters. We see that there are clear local maximums with a smooth increase in R-sqaured to the calibrated parameter values.

6 Counterfactual Analysis

In this section I provide counterfactuals by taking two approaches. The first is using the reduced form gravity equation with importer year and exporter year fixed effects. Although this is the most prevalent way of analyzing trade behavior, the drawback is that general equilibrium effects cannot be properly controlled for. The second approach uses the universal gravity general equilibrium model. I look at three counterfactuals. The first is a scenario in which none of the improvements in borders or ports were enacted between 2008 and 2014. The second is a scenario of borders being at least as efficient as 3 hour wait times. The last scenario is to assign all ports in the SADC and EAC the same efficiency as Chinese ports in terms of costs. Each of these scenarios will be first analyzed in an aggregate setting and then broken up into three sectors of agriculture, manufacturing, and resource commodities.

6.1 No Border Improvements

Table A23 illustrates the general equilibrium effects on trade from assuming that no border improvements were made between 2008 and 2014 and that border wait times were that of 2008 levels. We see in the agriculture sector, taking a weighted average with respect to countries' income, that trade would be negatively affected by 12.85 percentage points of the growth of internal trade during that period. This implies that instead of the actual 49.3% increase in agricultural trade during this period, it would be estimated to be 36.45% if no border improvements were made.

Table 5 disaggregates the effects between internal and foreign trade for each sector. We can see that manufactured goods traded internally would be hardest hit with an estimated decrease of 17.89 percentage points from the actual growth which was 102.26% over the time period. Converting this to actual dollar amounts and looking at all sectors, I find that 3.96 billion USD of the 18.6 billion USD increase in internal trade was generated by implementing the border improvements. Therefore, when including the .612 billion USD increase in foreign trade attributed to reduced border frictions we can begin to calculate the benefit of improved border crossings at an estimated 4.57 billion USD. A report by the SADC estimated the cost of improving many of the larger border crossings to be anywhere between 3.5 million USD and 25 million USD. This suggests that the borders quickly pay for themselves and provide significant value in terms of trade every additional year that they are maintained.

Table 5: Percentage point change in trade patterns with no improvements: for internal and foreign trade. Universal gravity model approach

Country	Inter trade Agriculture	Inter trade Manufacturing	Intertrade Resources	Foreign trade Agriculture	Foreign trade Manufacturing	Foreign trade Resources
Angola	-21.40	-17.34	-13.30	-6.81	-2.79	-1.08
Botswana	-28.40	-35.03	-57.57	-0.67	15.73	-5.62
Burundi	-36.25	-16.73	-29.66	-17.31	-98.54	-22.59
Congo; Dem. Rep.	-37.14	-29.13	-39.03	-13.12	-75.62	-10.25
Kenya	-18.53	-80.06	-7.70	-2.00	-5.51	0.70
Lesotho	-6.23	-27.61	-17.18	2.32	-28.06	4.06
Malawi	-22.16	-11.35	-3.80	-6.95	-34.04	-6.43
Mozambique	-47.91	-29.94	-48.55	-1.90	14.06	-8.89
Namibia	4.64	36.45	1.67	1.49	7.83	1.15
Rwanda	-0.42	-59.82	-6.57	-5.75	-12.78	6.34
South Africa	-8.73	-6.41	-1.75	0.51	14.95	0.89
Swaziland	-15.19	-82.37	-11.17	1.96	-5.01	-6.98
Tanzania	-12.11	-18.33	-8.18	-2.68	2.88	-1.94
Uganda	-0.21	-35.51	-13.00	-4.67	-23.18	-3.11
Zambia	-7.97	-5.58	-14.48	0.97	14.63	2.62
Zimbabwe	-1.74	23.79	-3.09	0.86	28.10	-1.96
Weighted Avg	-13.87	-17.89	-9.52	-2.15	3.04	-0.71

6.2 Efficient Border Crossings

Next, I create a hypothetical scenario in which border waiting ti are reduced to 3-hours, similar to that between OECD countries who have established border crossings. Table A27 shows overall percentage point changes to trade expected from having no borders. This scenario would lead to agricultural trade growth of 60.44% between 2008 and 2014 instead of the actual 49.3%. Trade in manufacturing products would see smaller increases with an added 4.32% over the time period with resource trade seeing an additional 9.2% increase. Splitting up trade between internal trade and foreign trade shows that internal trade would significantly increase, particularly in manufacturing products, while foreign trade would stay relevantly constant or even decrease.

6.3 Ports Like China

Allowing for the ports to have the same efficiencies as those in Chine, which were the most efficient ports according to the 2014 Doing Business surveys, Table A29 shows the estimated counterfactual of increased port efficiency when using the fixed effects gravity estimation described in section 5.1. The reduced form approach has the disadvantage of not accounting for general equilibrium effects. Therefore, decreasing port costs would have no effect on trade between countries in the SADC and EAC. The results show that trade in manufacturing goods would gain the most, a 5.7% increase, and that landlocked countries stand to benefit most. Agricultural products would see the least increase in trade with the rest of the world.

Using the universal gravity model, Table A25 shows similarities among the benefits due to improved ports, with manufacturing seeing the largest gains at 6.03%. Agriculture and resource trade would improve 2.9% and 2.0% respectively. Breaking up trade by exports to the rest of the world, we see large increases in manufacturing (7.6%) and agriculture (3.5%) with little effect on resource trade (0.6%). Unlike with the reduced form counterfactual, here we can begin to look at the effects of port conditions on trade between SADC and EAC countries. On average, the effects of increased port efficiency would be negligible. However, some countries could see moderate effects. Zimbabwe, for instance, would see a 1.2% decrease in resource exports to other countries in the SADC and EAC.

7 Conclusion

It has been argued thoroughly that insufficient transportation infrastructure is one of the main components in limiting trade and, consequently, growth within developing countries. This is particularly true in Africa where many landlocked, remote or low population density countries have to trade with large within and cross border transportation frictions. This topic also concerns the facilitation of regional integration, particularly through large-scale investments by governments and NGOs to strengthen domestic trade and development. However the usual inter dependence of transportation infrastructure, trade and development make it difficult to determine the actual effects that additional investments in transportation infrastructure would have on integration, trade and thus development.

Furthermore, the effects of transportation infrastructure such as roads, ports, and borders on trade flows have been empirically difficult to study due to the dichotomy between countries who have large transportation infrastructure projects who have sparse trade flow data, and the countries who have ample trade flow data, but little time variation in their transportation infrastructure over data available time periods. This paper begins to bridge this gap by looking at a multi country region that has significantly reduced trade costs due to investments in border and port infrastructure in a relatively short period of time.

This paper contriubutes to the discussion by finding that the improvements in border crossings throughout southern and eastern Africa have contributed to the overall trade increase with significant benefits to intra-regional trade in manufacturing and agriculture. The paper also shows the importance of methodologies not found regularly in the literature such as using reduced form verses general equilibrium results, excluding certain trading partners like the outside world or disregarding multi-modal transportation. Allowing for the analysis to include other modes of transportation such as air and rail would give a deeper understanding of how infrastructure can affect trading behavior.

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