Border Crossings and Trade in SADC and EAC

Alexander Pearson

January 4, 2017

Abstract

This paper uses a general equilibrium gravity model to estimate the effects of transportation infrastructure improvements on trading behavior. I use the reduction of border wait times and increased port efficiency in South and East Africa as the natural experiment, a region that has seen very little intra-regional trade. I solve the model for multiple sectors and allowing for trade with the rest of the world. The reduction of border wait times from a 30 hour average to 10 hours is estimated to have increased trade from 48.7% increase without recent improvements to 70.9% over 7 years with inland countries having a greater benefit. I then compare the reduced form gravity equation estimations with that of the general equilibrium model in a series of counterfactuals and find larger gains when accounting for both direct and indirect effects that the GE model provides most significantly for the manufacturing sector.

1 Introduction

Although geographically close to one another, countries in Sub-Saharan Africa trade relatively little with one another. Intra-Regional trade in SSA is 10% of total trade compared to 60% in Europe, 53% in Asia, 50% North America, and 26% in South America. Models that account for economic size, geographical distance along with other characteristics such as common language and exchange rates, predict trade flows that would be higher than what are observed (World Bank 2009). Similarly, the Linder Hypothesis (Linder 1961, Bernasconi 2013, Fajgelbaum et al 2011) which states countries that have similar characteristics, usually measured in the literature by income distributions, will trade more with each other seems not to apply to countries in SSA.

This has not been a result of a lack of effort. 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 a formation of 14 regional economic communities (RECs) of which each country is a member of at least one REC with many countries being a member of several. These RECs have predominantly been focused on reducing the tariffs of goods between each member country with mixed results (World Bank 2012). Other characteristics of the region such as poor transportation infrastructure and high non-tariff barriers have thought to have a higher impact on the low trade between countries. For instance, in 2008 crossing over from the Democratic Republic of Congo to Zambia, took an average of 96 hours on top of having to drive on poor conditioned roads and completing an average of 16 documents. However, studies looking at the effect of transportation infrastructure and non-tariff barriers on trade flows are sparse or inadequate. This can be problematic for countries that have limited resources to choose which projects to invest in such as cross border facilities, roads, ports, or regulatory rules and implementation in order to promote trade with other countries. Indirect effects on trade flows by changing trade costs further complicates the issue. Lowering costs to trade between two regions will presumably increase the trade between the two but can have positive or negative effects on trade with other regions that were not part of the reduced trade costs directly.

This paper provides a framework to incorporate these additional trade frictions into a general equilibrium gravity trade model developed by Allen et al (2014). I focus my attention on two major RECs, the Southern African Development Community (SADC) and the East African Community (EAC), who have shown high interest in integration both within and between themselves. One prominent development within these RECs have been the implementation of one stop border posts (OSBP) and ongoing performance surveys which have shown a significant reduction in border wait time leading to several days saved at many borders. With these surveys, data on the distribution and conditions of the road network for each country and product specific tariffs, I construct transportation costs from the 16 countries within the two RECs to every other country in the sample for 2008 and 2014, the time in between which most of the OSBPs were implemented.

The exclusion of trade with the rest of the world, although prevalent in infrastructure and trade literature, may distort estimates and limit the papers analyses of intra and inter regional trade. Therefore this paper includes trade with all other trading partners and provide methods to merge transport costs due to road and border crossings and costs due to port and sea transport. Incorporating trade with the rest of the world and allowing for a gravity model with multiple sectors can provide insights on whether transportation improvements provides the most benefit too certain sectors. This may benefit countries, especially in Sub Sahara Africa, who are concerned that reduced transportation costs may bring a flood of cheap manufacturing goods and an increase in the exportation of their limited non renewable resources.

To illustrate the advantages of this framework I use a series of counterfactuals that show how intra regional trade was affected by various infrastructure changes. For instance, if neither port nor border improvements were made between 2008 and 2014. These range from reducing border wait times to those seen in OECD countries, improving port efficiencies to that of China, and implementing the regions Development Master plan that outlines future infrastructure projects planned for the next 15 years in the SADC and EAC. To see how the recent infrastructure improvements affected the share of trade between countries in the SADC and EAC, I also include counterfactuals where no border improvements occur.

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

The paper is organized as follows. Section 2 will provide a brief overview of the literature. Section 3 will cover the relevant data used. Section 4 will provide the theoretical framework used to guide the empirical analysis section 5 will discuss the empirical strategies used, section 6 will be the results section and section 7 will conclude.

2 Literature Review

The question of why African countries have such low trade with one another relates to a substantial literature of border effects and their relation with trade flows. The border effect puzzle came to attention with the seminal work of McCallum (1996) who found abnormally large estimates of borders affecting trade flows between the US 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 [1] Anderson van Wincoop(2003) provided an expla-

[1] These studies include studying 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 accounting for other variables (Hliberry (1999), Wei (1996), Frankel and Wei (1998), Anderson van Wincoop (2003), Chen (2004), and Millimet and Osang (2007).

nation to why McCallums(1996) study found grossly overestimated border effects [2] stating that not accounting for multilateral resistance variables such as remoteness leading to omitted variable bias.

Even accounting for remoteness, Anderson van Wincoop (2003) still find a sizable border effects between Canada and America. In their paper over the 6 major puzzles of international trade, Reinhart and Rogoff (2000) discuss that transportation costs still plays a dominant role in explaining why these puzzles remain. However, almost all the studies mentioned above, use distance and tariffs to account for transportation costs. Although tariffs were the major contributor to increased international trade over the last half century (Baier and Bergstrand (2001)), tariffs have been reduced to near negligible levels that other costs to transport will be more significant in explaining the border effect. Although this area of research is relatively untouched a few papers do use other methods to measures of 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, the better connectivity within countries accounts for 25 percent of the negative effect that borders have between countries. Studies have also tried to apply this gravity equation approach to trade between African countries. Uduak S, Akpan looked at the Economic Community of West African States (ECOWAS) and estimated a gravity equation using distance and percent of road paved to account for transportation costs.

Although the study of border effects have somewhat neglected transportation infrastructure in their empirical analysis, intra-country transportation infrastructure studies have been more prevalent. Chandra and Thompson (2000) and Michaels, look at how U.S rural cities were affected by highways that connected major cities through the 1950?s onwards. Banerjee et al. (2012) and Baum-Snow et al. (2013)

[2]Canadian provinces were estimated to trade 22 times more with other provinces rather than America.

have similar analysis for China's road and rail development. Storeygard (2013) look at the connections between hinterland cities in SSA to near major port cities and find that the quality of connection affects the rural cities income, measured by night time luminosity. Storeygard (2015) 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 (2003), to obtain general equilibrium impacts to 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 look at colonial India to see how trade flows and welfare changed from the expansion of the railroad system. Alder (2015) estimated the welfare effects using luminosity data of the construction of the Golden Quadrilateral Highway network and compared that to the road network that was constructed in China during the same period. Allen and Arkolakis (2014) create a general equilibrium model that incorporates the topography of the region and determined that location accounts for at least twenty percent of the spatial variation in U.S income.Studies have also looked at the variation of prices of commodity goods due to changes in transportation infrastructure. Sotelo 2015 finds that an average farmer gains 16 percent in productivity and 4 percent in welfare due to paving existing dirt roads in Peru. Atkin and Donaldson 2014 provide a method of dealing with issues using the price gap as a means of estimating trade costs and find that within country trade costs due to log distance is four to five times larger in Ethiopia and Nigeria than it is in the United States.

3 Data

In order to capture transportation costs , I first create a transportation network database for 2009 that contains the quality of the roads and the border crossing characteristics between each country in the SADC and EAC (16 countries in all) which allows me to calculate travel times to bilateral trading partners. The main data source will be taken from the Center of International Earth Science Information Network (CIESIN) and the African Development Bank Group. This data provided for 2010 provides details of the road networks in each country of the SADC and EAC. The data includes information on road types and conditions.

Since there has not been any 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 done 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 that had a poor or fair condition, a speed value of 40 km/h was assigned. For unpaved dirt or gravel roads, a speed of 25km/h was given. Locations that did not have any transportation networks, I assign a speed of 10 km/h to account for potential small unobserved trails.

For border crossings, I use survey data from 33 different crossings between each country 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 do not have survey data for that crossing, an average of the average wait times for each countries other border crossings were taken. Since many of the unreported borders are in low trafficking area's due to them being far away from large cities or main travel routes I also conduct a robustness check where the wait time for these unobserved border crossings is the average of low through traffic border found in World Bank (2010). Many border crossings took days to get across with the highest being 5 days on average. Other borders had very low wait times of a few hours. Many of the surveys also include monetary costs from regulations that have to be paid to cross the border. In this transportation network I only allow movement through the official border crossings.

With this transportation network, I then begin to construct transportation costs from each country in my sample to the other. While there have been a number of different methods of modeling transportation costs, Roberts (2010) has shown that travel times provide a suitable proxy for overall transport costs. In order to obtain transportation time in 2010 from the constructed transport networks, I use a Dijkstra algorithm in ArcGIS to find the shortest time travel 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 your beginning an ending points become important especially if there are many large cities in one country all importing and exporting to other countries and will have different travel costs. To get around this issue I take the top 3 to 5 cities in each country and find the travel costs to get to every other city in the other countries. I then use a weighted average using satellite luminosity data for each city in the two country pair to get an average travel time between those two countries.

Bilateral Trade flow data was taken from UN Comtrade for the year 2008 and 2014.[3] I use the 2 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 the other countries that did report to construct their imports. For trade with the rest of the world I combine countries into 6 separate groups. These are North America, 27 countries of the European Union, Asia, North America, South America, and the rest of Africa. Table 18 shows the change in trade flows by sector and internal/foreign trade. We see that during this trade between other countries in the SADC and EAC saw significant gains compared to trade to foreign regions. This is especially true for the agriculture and manufacturing sectors. Indeed manufacturing trade is nearly half of total manufacturing trade.

Tariff data is obtained by two WTO databases, the Integrated Database and the Consolidated Tariff Schedules. This data base also provides whether specific countries have certain trade agreements with each other. If no such trade agreement

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

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 are obtained from the Worldwide Governance Indicators.

3.1 Multi Modal Transportation

Several papers forgo the inclusion of interactions that are outside of the study area [4]. 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 their corresponding trade costs can have the potential of significantly changing the outcome of ones result. This is even more of a concern in this case study since 85 percent of total trade is with countries outside the study region.

The largest hurdle to incorporate different modes of transportation into the transportation network is to provide a unit cost or ad valorem cost that is compatible between each mode. This practice is still in its infancy when it comes to incorporating multi modal transportation into a general equilibrium trade model with no consensus on how this should be done. In SEA, road transportation is the predominant method of transportation with the region where sea trade is mostly used for trading with the rest of the world [5]. In order to include the transportation network with the rest of the world, costs pertaining to port usage needed to be acquired. To

[4] Donaldson and Hornbeck (2014) allow for trade to take place over water but only to other areas in the U.S. Donaldson (2013) makes 4 areas that can trade internationally within the Indian area for the particular good of interest

[5] Air transportation is also relatively common when trading with the rest of the world to the order of _ percent. I exclude this and railway transportation in order to simplify an already complex problem.

do this I use the World Bank's doing business who survey local freight forwarders, customs brokers and traders in 189 countries. For each country they break 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 countries leading export [6] It is also assumed that the cargo is shipped from the largest city within their respective countries. Travel times and costs are also documented from the major city to the nearest border if the country is landlocked or port if they are not.

The survey also includes data on the time and costs it takes to go from the primary city to the port or border. This can give us an approximation on per hour costs for road transportation which I can then regress the cost to transport on time taken to port/border to get the average marginal cost of an additional hour of driving. Table 1 shows that every hour creates on average an additional 27 USD transport cost which is used for all times in the transportation network. 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 implemented in transporting goods across borders. One large unknown is the extent of road blocks and bribes play in each country. The transport cost to port or border data may have included this interaction but unlikely to give the detailed structure of road block locations and 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.

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

4 Theoretical Approach

A large variety of general equilibrium micro founded trade models provide a gravity gravity equation 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 homogeneous firms and intermediate inputs while Meltiz (2003) used hetrogenous firms. Eaton and Kortum used a Ricardian style perfect competetion and several other papers have extend onto these workhorse models. These models face difficulties in garanteeing uniqueness and charactarizing comparative statistics, often times using sub optimal assumptions to achieve these. Allen, Arkolakis and Takahashi (2014) provide a universal gravity model that nests these gravity models within which, with minimal assumptions, allows a uniqeness in equilibrium and closed form comparative statistics.

4.1 Model Setup

4.1.1 Single Sector Model

To set up the universal gravity model, the world is comprised of a set $S \in (1, \ldots, N)$ of locations. These locations can either be countries or smaller administrative areas. For each location I denote Y_i as the gross income and X_{ij} as the value of location j's imports from location i. Trading between each location is hampered by a corresponding trade friction represented by $K_{ij} > 0$. It represents the trade costs that are associated in trading between both locations such as, the inverse distance, time taken, tariffs ect. To account for many of the micro founded characteristics found in modern trade models such as wages, prices, productivities and labor endowments, I define, as in Allen 2015 (γ_i) and (δ_j) to be the exporting and importing ?capacity? respectively. These two variables are solved endogenously within the general equilibrium model allowing us to make less assumptions of the underlying mechanisms that many of the seminal trade models focus on while still providing the same outcome. Allen (2015) shows that 4 conditions must be met in this framework in order to obtain the general equilibrium outcomes found in many of the current workhorse trade models.

The first condition characterizes trade flows in a gravity like equation found in many trade models.

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

$$X_{ij} = K_{ij}(\gamma_i)(\delta_j) \tag{1}$$

For example in the Eaton and kortom model the import shifters would be the income and competitiveness of locations around I and the export shifters would be the productivity and wages of the exporting location (Need to look this up better). This equation was first introduced by Tinbergen (1962) and has gained significant empirical traction over the years.

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

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

$$Y_i = \sum_j X_{ij} \tag{2}$$

That is the total sum of all purchases from all locations, including its own location, is equal to their income for all locations.

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

$$Y_i = \sum_j X_{ji} \tag{3}$$

That is all exports, including the "exports" to their own location, must equal to their income. Although common in the trade literature, this condition is rarely holds for countries. Allen 2015 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 $i \in S$

$$Y_i = B_i \gamma_i^{\alpha} \delta_i^{\beta}, \tag{4}$$

where $\alpha \in \mathbb{R}$ and $\beta \in \mathbb{R}$ 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, I estimate (α and β) in order to allow for welfare analysis and counter factuals.

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

Condition 5 World income equals to one.

$$\sum_i Y_i = 1 \tag{5}$$

To define the equilibrium system of equations that satisfy these conditions we can use equations 2 and 3 and substitute out X_{ij} and Y_i with equations 1 and 4. This gives

$$B_i \gamma_i^{\alpha-1} \delta_i^{\beta} = \sum_j K_{ij} \delta_j \tag{6}$$

and

$$B_i \gamma_i^{\alpha} \delta_i^{\beta-1} = \sum_j K_{ji} \delta_j \tag{7}$$

and with equations 3 and 5, Condition 5 can be written as

$$\sum_i B_i \gamma_i^\alpha \delta_i^\beta = 1 \tag{8}$$

Therefore, Allen et al (2015) state that for any given gravity constants (α and β), income shifter $\{B_i\}$ and the bilateral trade frictions $\{K_{ij}\}$, and defines a general equilibrium gravity model to be a set of export shifters γ_i and shifters δ_i that satisfy equations 6, 7 and 8.

4.1.2 Multi Sector Model

A large contribution of SSA trade comprises of lower value input goods such as resources and agriculture and trade in manufacturing, particularly in light manufacturing has been stifled due to poor policies and infrastructure. This leads to potential questions into whether reducing To account for this I extend the gravity model to include 3 sectors, agriculture, manufacturing and resource extraction. Again using work done by Allen et al. (2015) let $s \in \{M, A, R\}$ be the set of sectors and the trade flows from location i to j be

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

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 what is assumed here. Now K_{ij}^s is interpreted as sector specific trade frictions letting different commodities to have different costs for transport. Condition 4 can be written as

$$Y_i = B_i \gamma_i^\alpha \left(\prod_s (\delta_i^s)^{\theta s} \right)^\beta$$

with the two remaining conditions being:

$$\sum_j X_{j,i}^s = B_i^s Y_i$$

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

Where the first equation assumes that the sum of the expenditures is a constant fraction of total income and the second equation is the goods market clearing condition. θ^s can be seen as the sensitivity of sectors s's export shifter in respect to income.

4.2 Comparative Statistics

To see how trade frictions affect welfare and trade flows in the model, I take advantage of the work done by Allen et al (2015) who derive comparative statistics for the importer exporter shifters. It is easy then to show the general equilibrium effects for trade and welfare at any location given a change in trade frictions between any locations.

4.2.1 Single Sector Comparative Statistics

As in Allen et al 2015 let X be an NxN matrix of observable trade flows where each $< i, j >$th element is X_{ij} and Y be the NxX diagonal income matrix where Y_i is the ith diagonal element. To define expenditure of each location i, let $E_i = \sum_j X_{ji}$ and define E to be the NxN diagonal expenditure matrix where the ith element is E_i. To ease notation, let

$$\mathbf{A} \equiv \begin{pmatrix} (\alpha - 1)\mathbf{Y} & \beta\mathbf{Y} - \mathbf{X} \\ \alpha\mathbf{E} - \mathbf{X}^T & (\beta - 1)\mathbf{Y} \end{pmatrix}$$

and define A^+ to be the Moore-Penrose pseudo-inverse of A and A_{kl} to be the $< k, l >$th element A^+. Allen et al 2015 propose that if A has rank 2N-1 then

$$\frac{\partial ln\gamma_l}{\partial lnK_{ij}} = X_{ij} \times (A^+_{l,i} + A^+_{N+l,j} + c)$$

and

$$\frac{\partial ln\delta_l}{\partial lnK_{ij}} = X_{ij} \times (A^+_{N+l,i} + A^+_{l,j} + c)$$

Where c is a scalar that is dependent on the normalization condition used for condition 5. Since trade flows and location incomes are determined solely by the importer exporter shifters, it is easy to find close formed solutions to the elasticities of trade flows and incomes with respect to trade frictions. Specifically, the effect of changing i and j's trade frictions has on l and k's trade flows can be expressed as

$$\frac{\partial lnX_{kl}}{\partial lnK_{ij}} = \frac{\partial ln\gamma_l}{\partial lnK_{ij}} + \frac{\partial ln\delta_l}{\partial lnK_{ij}} = X_{ij} \times (A^+_{N+l,i} + A^+_{l,j} + A^+_{l,i} + A^+_{N+l,j} + 2c)$$

Similarly, the effect of changing i and j?s trade frictions has on l?s income can be expressed as

$$\frac{\partial lnY_l}{\partial lnK_{ij}} = \alpha\frac{\partial ln\gamma_l}{\partial lnK_{ij}} + \beta\frac{\partial ln\delta_l}{\partial lnK_{ij}} = X_{ij} \times (\alpha(A^+_{l,i} + A^+_{N+l,j} + c) + \beta(A^+_{N+l,i} + A^+_{l,j} + c))$$

4.2.2 Multi Sector Comparative Statistics

The addition of multiple sectors follows the same method as the single sector case above [7]. Appendix 6.1 describes the construction of the multi sector comparative statistics in detail. It is possible now to have a change in transportation frictions in a specific sector between two countries affect trade between any other country pair and sector. Specifically:

$$\frac{\partial\gamma_l}{\partial K^s_{ij}} = X^s_{ij}(A^+_{l,i} + A^+_{l,N+j}) - c^s_{ij}$$

and

$$\frac{\partial\delta^{s'}_l}{\partial K^s_{ij}} = X^s_{ij}(A^+_{(s'N+l),i} + A^+_{(s'N+l),N+j}) - c^s_{ij}$$

[7]The construction of the comparative statistics for the single sector model can be found in the online appendix of Allen (2014)

where A^+ is a $(N+SN)\times 2N$ matrix and the moores 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

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

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 pegs these values down to our assumption of condition 5 which states that world income equals one [8].

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.

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

[8] Specifically:

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

5 Empirical Analysis

5.1 Reduced Form Gravity Equation Estimation

For the Empirical analysis, I begin by estimating the gravity equation represented by equation (_)in section 4. Applying logs and allowing for time variation one gets

$$\ln(X_{ijt}^{s}) = T_{ijt}\mu + \ln\gamma_{it} + \sum_{s} I_s \ln\delta_{jt} + \epsilon$$

Where T is a vector of observables (time costs), I_s is the indicator function and

$$\ln K_{ijt} = T_{ijt}\mu$$

denotes the type of industry the traded good comes from. The UNCOMTRADE data uses the harmonized system coding that categorizes products into 97 different products (99 if including services).

Gravity equations have been used extensively to estimate a wide variety of determinants to trade [9]. Taking advantage of the many border crossing surveys over time, I will be able to exploit the time variation to determine the effect of improved infrastructure on trade flows.[10] To account for any lag in the response of trade to changes in trade frictions, I conduct a long difference estimation with importer-year-sector and exporter-year-sector fixed effect between the period of 2008 and 2014 where all of the surveys and improvements were implemented. These fixed effects will be able to account for the unobservable that our model indicates that determine trade flows such as productivity and labor and labor rents. This method also absorbs variables that we do observe but are time and country specific such as income. This limits the analysis by refraining our able 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. These

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

[10]One draw back from this method is that the model is created in a static environment and is used to estimate a time varying phenomenon.

97 products can be sub divided in 15 sectors found in table (Still need to put this is :`http://www.foreign-trade.com/reference/hscode.htm`) to reduce the matrix size to reasonable levels [11] I then reduce this down to 3 sectors, agriculture, manufacturing and resources for the analysis of the general equilibrium model to ease computation.

Ideally the changes in border crossings would come from events that were exogenous to countries decision to trade with one another. This reverse causality would lead to an upward bias in our estimates. For instance if two countries are expected to trade more with each other in the future (this may be from past trade missions they have had with each others business leaders ect.) then this fact may lead these two countries to improve their border crossings to allow an easier movement of goods. In this scenario, the goods would have been moved regardless and the improved border crossings would have little effect. However, a key characteristic of having many countries in the same region. Even if the above scenario did take place a third country that has to use that border crossing to get to their other trading partner now has a exogenous change in their transportation costs, since they presumably have very little say on how the first two countries improve their transportation network (i.e Mexico deciding for America and Canada to lower border crossings because Mexico expects to trade more with Canada). Therefore, looking at countries that do not share boarders will let us look at how a reduction of other countries border times affect their trade decisions without border crossings being related to expected trade flows. Another potential concern is the endogeneity trade flows may have on border times when it comes to queuing. All else being equal, an increase in trade going 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 for everyone. This would lead to the wrong conclusion that higher wait times leads to higher volumes of trade. Again I will argue that how the study area is characterized, this endogenous effect is mitigated, since only 10-15 percent of what is traded on the studied transportation network. Therefore any changes in trade flows between

[11] having 97 products with 21 countries would lead to 4074 dummy variables in the regression.

these countries will have a marginal effect on overall wait times. When I look at a full trade model incorporating foreign countries, this issue will become larger.

There has been a growing literature on the consequences of performing ols on logged functions and their effect on the error term as it appears to make the error terms heteroskedastic. Sylvos and (_) show that this can be accounted for by using other estimation techniques such as the Pseudo Poisson Maximum Likelihood estimator. Not only does this account for the heteroscedasticity in the error term but allows one to account for zeros in trade flow data where they would have been thrown out. This last benefit is less of a concern for this paper since most of the countries in the have positive trade flows during the time of analysis.

5.2 Model Estimation

5.2.1 Calibration of gravity constants, single sector case

Section 4 described a model in which for any given α and β, income shifters (B) and trade frictions K_{ijt} general equilibrium could be solved by a set of endogenous import and exporter shifters and identified the welfare elasticities. This subsection will address the estimation of α, β and a trade cost parameter using the trade flow and travel time data, which allows for the opportunity of counterfactuals and welfare analysis in section 6. The most straight forward strategy would be to use the gravity equation in equation (_) to retrieve estimates for δ and γ then use Condition 4's equations to estimate α and β. To illustrate, Define $\hat{x}$ $\hat{\delta}$ $\hat{\gamma}$ ...etc to be the change in the respective variables. Therefore

$$\ln \hat{X}_{ij} = \hat{T}_{ij}\mu + \ln \hat{\delta}_i + \ln \hat{\gamma}_j + \epsilon_{ij}$$

Once the estimates for $\hat{\hat{\delta}}$ $\hat{\hat{\gamma}}$ are obtained, the estimation of the gravity constants can be done by projecting the log income on the estimate $\hat{\hat{\delta}}$ $\hat{\hat{\gamma}}$

$$\ln \hat{Y}_i = \alpha \ln \hat{\hat{\gamma}} + \beta \ln \hat{\hat{\delta}} + \nu$$

An issue arises with this method however due to the unobserved income shifter $B\_i > 0$ found in equation (_) that will be incorporated with the error term ν allowing for correlation of $\hat{\hat{\delta}}$ and $\hat{\hat{\gamma}}$ with ν. This will increase the locations exports, through the market clearing condition, and imports, through being correlated with ν leading to an upward bias to the gravity constants. Treb et al (2015) provide another method that takes advantage of the general equilibrium structure of the model. The approach calculates the importer and exporter shifters directly from the model and predicts 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.

$$(\alpha^*, \beta^*, \mu^*) = arg \min_{\alpha,\beta \in \mathrm{I\!R}, \mu \in \mathrm{I\!R}^S} \sum_i \sum_j \left(\ln \hat{X}_{ij} - \hat{T'}_{ij}\mu - \ln \hat{\gamma}_i\big(\hat{T}\mu; \alpha, \beta\big) - \ln \hat{\delta}_j\big(\hat{T}\mu; \alpha, \beta\big)\right)^2$$

This can be done by first solving for μ in equation (_) given a set of α and β. To simplify the estimation procedure I follow Allen et al (2015) and take first order approximations to both $\ln \hat{\gamma}_i$ and $\ln \hat{\delta}_j$ such that

$$\ln \hat{\gamma}_i \approx \sum_k \sum_l \frac{\partial ln\gamma_i}{\partial lnK_{kl}} \hat{T}'_{kl}\mu$$

and

$$\ln \hat{\delta}_j \approx \sum_k \sum_l \frac{\partial ln\delta_j}{\partial lnK_{kl}} \hat{T}'_{kl}\mu$$

Therefore the μ that minimizes the squared error of equation (_) for a certain α and β can be written as

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

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

This implies that, to a first order approximation, one can solve for the optimal trade parameter μ^* by conducting an ordinary least square regression of the observed log change of trade flows on a general equilibrium transformed explanatory variable $\hat{T}_{ij}^{GE}$:

$$\ln \hat{X}_{ij} = \big(\hat{T}_{ij}^{GE}\big)'\mu + \epsilon_{ij} \tag{9}$$

Where

$$\hat{T}_{ij}^{GE} = \sum_k \sum_l \frac{\partial \ln \hat{X}_{ij}}{\partial \ln \hat{K}_{kl}} \hat{T}_{kl}$$

Again $\frac{\partial ln \hat{X}_{ij}}{\partial ln \hat{K}_{kl}}$ is composed of the gravity constants α and β, which have been taken as given so far, and observed trade flows. Solving for the optimal α^* and β^* that minimizes the total squared error from equation (_) gives

$$(\alpha^*, \beta^*) = arg \min_{\alpha,\beta \in \mathbb{R}} \hat{\boldsymbol{y}} \Bigg(\boldsymbol{I} - \hat{\boldsymbol{T}} \Bigg(\big(\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}}\big)' \big((\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}}\big)\Bigg)^{-1} \big(\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}})\big)' \Bigg) \hat{\boldsymbol{y}} \tag{10}$$

As in Allen et al (2015) I apply a grid search over relevant values of α^* and β^*.

5.2.2 Calibration of gravity constants, multiple sector case

Following the same steps for estimating the unknown parameters in the single sector case by taking the least squared errors between the observed change of trade flows from changes in trade costs to the predicted change.

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

Again allowing for a first order for $\ln \hat{\gamma}_i$ and $\ln \hat{\delta}_j^s$ to be

$$\ln \hat{\gamma}_i \approx \sum_s \sum_k \sum_l \frac{\partial ln \gamma_i}{\partial ln K_{kl}^s} \hat{T}_{kl}^{\prime s} \mu^s$$

and

$$\ln \hat{\delta}_j^{s'} \approx \sum_s \sum_k \sum_l \frac{\partial ln \delta_j^{s'}}{\partial \ln K_{kl}^s} \hat{T'}_{kl}^s \mu^s$$

Again I first estimate the set of optimal trade parameters μ^{s*} by ordinary least squares on the general equilibrium transformed explanatory variable $\hat{T^s}_{ij}^{GE}$:

$$\ln \hat{X}_{ij}^s = (\hat{T^s}_{ij}^{GE})' \mu^s + \epsilon_{ij}^s \tag{11}$$

Where

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

And

$$\frac{\partial \ln \hat{X}_{ij}^{s'}}{\partial \ln \hat{K}_{kl}^s} = \frac{\partial ln \gamma_i}{\partial ln K_{kl}^s} + \frac{\partial ln \delta_j^{s'}}{\partial \ln K_{kl}^s}$$

Using a 3 sector version requires 5 parameters to be solved. I first perform a grid search to limit the control space then taking the set of parameters perform a random search around those values to tune the parameters.

$$(\alpha^*, \beta^*) = arg \min_{\alpha,\beta \in \mathbb{R}} \hat{\boldsymbol{y}} \Bigg(\boldsymbol{I} - \hat{\boldsymbol{T}} \Bigg(\big(\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}} \big)' \big((\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}}) \Bigg)^{-1} \big(\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}}) \big)' \Bigg) \hat{\boldsymbol{y}} \tag{12}$$

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

6 Results

6.1 Gravity equation estimation results

Starting with the 15 sector case, table 3 in section 8.3, we can see that overall the reduction in trade costs between two countries from border and port improvements increased the growth of trade between them. This is also true when we look at trade solely between countries within the SADC and EAC letting us see that border reductions by themselves was followed by an increased in trade. When I disregard trade between adjacent countries within the study region I still find the same statistically significant results. A interesting result happens however when I only look at adjacent countries trade behavior. In column 8 we see that the coefficient is now positive meaning that the countries that are close to one another actually chose to trade with countries farther away. This could suggest that higher border costs push countries to trade geographically close to each other. This is somewhat intuitive since if a land lock country reduces border friction with their neighbor, it now has better access to the outside world. To reduce the risks of measurement error I again run this estimation with 3 year averages for each variable used. Table 4 has these results and follow the same conclusion of that in table 3.

To analyze the effects that institutional characteristics have on how trade behaves with travel costs. I include interaction effects for 4 different variables regulation quality, rule of law, political corruption and political stability. Table 6 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.

Table 7 shows the results when I organize trade into 3 sectors. Here we lose some significance in certain scenarios. The only case in which we see positive results from infrastructure improvements is when we look at SADC/EAC trade and exclude the outside world. The adverse result of looking at adjacent countries only still persists. Table 9 through 10 look at each sector separately in which the signs all point in the same direction but all significance is lost. This may be due to some products being affected differently causing the average to not tell us much. Tables 12 through 14 breaks down these 3 sectors back into the 15 sector framework to see if more information could be gathered. From this we see that chemicals and allied Products, raw hide/skins/leather/furs, footwear and headgear, and metals have shown increased trade from countries that had a reduction in their transportation costs.

Another interesting result found in each regression it the positive coefficient found on the log difference of tariff rates. [12]A possibility for this is that countries have some information of what products will be in high demand in the preceding years, therefore raising tariffs for those products would gather them greater revenue. Conversely if they are pressured to keep overall tariffs low, they may be inclined to lower tariffs on products that are not imported much into the country, since it will not affect their revenue substantially and it may increase imports over a longer time window than this paper studies.

6.2 General equilibrium calibration estimation results

Table 15 shows the results for equation 9 done with various gravity constants of alpha and beta. Row 1 shows estimates when minimizing equation 10 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) who 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 one percent 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 percent increase in trade flows with high statistical significance. Row 2 represents 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 and Row 4 are values found in Alvarez and Lucas (2007). The explanatory power from values of other papers appear to be low when applied

[12]When aggregating tariffs, I applied a weighted average towards the tariff that involved using the trade flow data for 2008. Using 2008 data for both 2008 and 2014 should not affect the results in a long difference estimations but this could be a miss judgment and using a previous date like 2007's trade flows may be more appropriate.

to the SADC and EAC. This may be due to developing countries behaving differently to transportation changes than developed countries where these other gravity constants were estimated from.

When looking at a 3 sector case and using the calibrated values for α and β found in the single sector model, we see large gains in our explanatory power of the data with the manufacturing sector but less with agriculture and resource extraction. All three sectors have negative and significant coefficients with manufacturing being largest magnitude.

6.3 Counterfactual results

In this section I provide counterfactuals by two different approaches. The first is using the reduced from gravity equation with importer year and exporter year fixed effects. Although the most prevalent way of analyzing trade behavior the draw back is that general equilibrium effects cannot be properly controlled for. The second approach uses the universal gravity general equilibrium model which I will compare the behavior of the effects of various counterfactuals. I look at 4 different counterfactuals. The first is the scenario where non of the improvements in borders or ports were enacted between 2008 and 2014. The second is the scenario of borders being at least as efficient as 3 hour wait times. The third is to change all ports in the SADC and EAC to have the efficiency as Chinese ports in terms of costs. The Last scenario looks at a scenario where trade frictions actually increase between each border. Each of these scenarios will be analyzed in an aggregate setting and broken up into 3 sectors, agriculture, manufacturing, resource commodities.

6.3.1 No Border Improvements

Table 19 illustrates the effects on trade from the transportation network staying at 2008 levels using the fixed effects gravity estimation popular in the literature. We see that modest decreases in all sectors with manufacturing seeing the largest losses. Table 20 splits the change into trade between countries in the SADC or EAC (internal) and trade with outside countries (foreign). Larger decreases are seen in trade between SADC and EAC countries with countries that where landlocked having the most burden.

Using the universal gravity model we see larger effects over the 7 year period with landlocked countries seeing significant decreases as well.

6.3.2 Lowering Border Costs

6.3.3 Ports like China

Allowing for the ports to have the same efficiencies as China's ports in 2014, table 23 shows the estimated counterfactual of increased port efficiency when using the fixed effects gravity estimation found in section 5.1. The reduced form approach has the disadvantage of not accounting for general equilibrium effects. Therefore decreasing port costs will have no effect on trade between countries in the SADC and EAC [13]. The results show that trade in manufacturing goods will gain the most with 5.7 percent increase with many of of the large benefactors coming from landlocked countries. Agriculture products see the least increase in trade with the rest of the world.

Using the universal gravity model table 21 shows similarities in the increased benefits of improved ports with manufacturing seeing the largest gains at 6.03 percent. Agriculture and Resource trade improved 2.9 and 2.0 percent respectively. Breaking up trade first with exports to the rest of the world we see large increases in manufacturing (7.6 percent) and agriculture (3.5 percent) with little effect on resource trade (0.6 percent). ' Unlike with the reduced form counterfactual, we can begin to look at the effects of the trade between SADC and EAC countries. Overall on average, the effect of increased port efficiency are negligible. However there are some countries that do see moderate effects. Zimbabwe for instance would see a 1.2 percent decrease in resource exports to other countries in the SADC and EAC.

[13] In the case I allow for SADC and EAC countries to trade with each other by sea this would not be the case. However internal trade would still move less than what would be expected due to not accounting for trade dispersion

6.3.4 Development Master Plan

7 Conclusion

The paper finds that the improvements in infrastructure 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 including various characteristics 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 greater depth of understanding of how infrastructure can effect trading behavior.

References

[1] Baier, Bergstrand 2007. *Do free trade agreements actually increase members international trade?*. Journal of International of Economics 71: 72-95.

[2] Baier, Bergstrand and Feng 2011. *Economic integration agreements and the margins of international trade*. Journal of International Economics 93(2):339-350

[3] Caliendo and Parro 2012. *Estimates of the Trade and Welfare Effects of NAFTA*. NBER Working Paper No. 18508

[4] Cassim 2001. *The Determinants of Intra-Regional Trade in Southern Africa with Specific Reference to South African and the Rest of the Region* . Development Policy Research Unit Working Papers.

[5] Cheng and Wall 2005. *Controlling for Heterogeniety in Gravity Models of Trade and Integration*. Federa Reserve Bank of St. Louis Review, 87 (1):49-63.

[6] Dekle, Eaton and Kortum 2008. *Global Rebalancing with Gravity: Measuring the Burden of Adjustment*. IMF Staff Papers, 55(3), 511-540

[7] DeRosa 2008. *Prospects for Greater Global and Regional Integration in the Maghres*. Peterson Institute of International Economics

[8] Tefler 1993. *Trade liberalization and the theory of endogenous protection*. Journal of Political Economy

[9] Tefler 2004. *The long and short of the Canada-US free trade agreement*. AER 94(4), 870-895.

[10] Foote 2009. *Economic Integration in Africa: Effectiveness of Regional Agreements*. University of Notre Dame.

[11] Makochekanwa 2012. *Impacts of Regional Trade Agreements on Trade in Agri food Products: Evidence from Eastern and Southern Africa* .

[12] Seid 2013. *Regional Integration and Trade in Africa: Augmented Gravity Model Approach* .

[13] Silva and Tenreyro 2006. *The Log of Gravity: The Review of Economics and Statistics*.

[14] Simon 2016. *Chinese Roads in India: The Effect of Transport Infrastructure on Economic Development*. Working Paper

8 Appendix

8.1 Appendix A.1 Comparative Statistics and Calibration for Multi Sector Model

8.1.1 Comparative Statistics

To calculate the comparative statistics I follow the same method as in Allen (2014). Define $y_i \equiv \ln \gamma_i$, $z_i^s \equiv \ln \delta_i^s$ and $k_{ij}^s \equiv \ln K_{ij}^s$. Let $\vec{y} \equiv \{y_i\}$ and $\vec{z^s} \equiv \{z_i^s\}$ all be $N \times 1$ vectors and let $\vec{x} \equiv \{\vec{y}; \vec{z^1}; \ldots; \vec{z^s}\}$ be a $(N+S) \times 1$ vector. Let $\vec{k^s} \equiv \{k_{ij}^s\}$ be a $N^2 \times 1$ vector and $\vec{k} \equiv \{\vec{k^1}; \ldots; \vec{k^s}\}$ be a $SN^2 \times 1$ vector. Using our equilibrium conditions in equations (_) and (_) we can define a function

$$f(\vec{x}, \vec{k}) \equiv \begin{bmatrix} [B_i(\exp\{y_i\})^\alpha(\prod_s(\exp\{z_i\}^{\theta_s})^\beta) - \sum_s \frac{1}{B_i^s} \sum_j K_{ij}^s \exp\{y_i\} \exp\{z_j^s\}]_i \\ [B_i(\exp\{y_i\})^\alpha(\prod_s(\exp\{z_i\}^{\theta_s})^\beta) - \sum_s \sum_j K_{ji}^s \exp\{y_j\} \exp\{z_i^s\}]_i \end{bmatrix}$$

Given the equilibrium conditions in the model:

$$f(\vec{x}, \vec{k}) = 0.$$

Fully differentiating and using the implicit function theorem gives:

$$f_{\vec{x}} D_{\vec{k}}(\vec{x}) + f_{\vec{k}} = 0$$

where $f_{\vec{x}}$ is the $2N \times (N + SN)$ matrix:

$$f_{\vec{x}} = \begin{pmatrix} (\alpha - 1)Y & \beta\theta_1 Y - X^1 & \ldots & \beta\theta_s Y - X^s \\ \alpha Y - X^T & \beta\theta_1 Y - E^1 & \ldots & \beta\theta_s Y - E^s \end{pmatrix}$$

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

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

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. $f_{\vec{k}}$ is a $2N \times SN^2$ matrix such that

$$f_{\vec{k}} = \begin{pmatrix} \Phi^1 & \ldots & \Phi^s \end{pmatrix}$$

Where Φ^s are $2N \times N^2$ matrices given by

$$\Phi^s = -\begin{pmatrix} X_{11}^s & \dots & X_{1N}^s & 0 & \dots & 0 & \dots & 0 & \dots & 0 \\ 0 & \dots & 0 & X_{21}^s & \dots & X_{2N}^s & \dots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & X_{N1}^s & \dots & X_{NN}^s \\ X_{11}^s & \dots & 0 & X_{21}^s & \dots & 0 & \dots & X_{N1}^s & \dots & 0 \\ 0 & \ddots & \vdots & 0 & \ddots & \vdots & \dots & 0 & \ddots & \vdots \\ 0 & \dots & X_{1N}^s & 0 & \dots & X_{2N}^s & \dots & 0 & \dots & X_{NN}^s \end{pmatrix}$$

As in Allen (2014) I solve for $D_{\vec{k}}(\vec{x})$ by using the moores psuedo inverse of $f_{\vec{x}}$ denoted as A^+

such that

$$D_{\vec{k}}(\vec{x}) = -A^+ f_{\vec{k}}$$

Therefore the solution can be expressed as

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

and

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

To determine the value of c, I use the world income assumption in condition 5 [14] which implies:

$$\sum_l B_l \gamma_l^\alpha (\prod_s (\delta_i^s)^{\theta_s})^\beta = Y^W \implies$$

$$\sum_l Y_l \Big(\alpha \frac{\partial \gamma_l}{\partial K_{ij}^s} + \sum_{s'} \beta \theta_{s'} \frac{\partial \delta_l^{s'}}{\partial K_{ij}^s} \Big) = 0$$

Therefore

[14] equation (_) as described in Allen (2014) has infinitely many solutions that correspond to different normalizations that can be applied by using Walras Law.

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

8.2 Appendix A.2: Solving model for counterfactuals

For this section I show, using work done by Allen et al (2014), how to solve the universal gravity model using Schauder's fixed point theorem both in a single and multi-sector case.

8.2.1 Single Sector

The key point in solving the general equilibrium trade model is to transform the model into a system of equations where a fixed point can be obtained and is unique. [15] As in Allen et al 2014, I begin by defining $x_i \equiv B_i \gamma_i^{\alpha-1}\delta_i^{\beta}$ and $y_i \equiv B_i\gamma_i^{\alpha}\delta_i^{\beta-1}$. x_i and y_i are characterized by the left hand side of equation 6 and 7 respectively. solving for γ_i and δ_i we get $\delta_i = x_i^{\frac{\alpha}{\beta+\alpha-1}} y_i^{\frac{1-\alpha}{\beta+\alpha-1}} B_i^{\frac{1}{\beta+\alpha-1}}$ and $\gamma_i = x_i^{\frac{1-\beta}{\beta+\alpha-1}} y_i^{\frac{\beta}{\beta+\alpha-1}} B_i^{\frac{1}{\beta+\alpha-1}}$. Therefore the equilibrium conditions of equations 6 7 and 8 found in section 4 can be rewritten as

$$x_i = \sum_j K_{ij} B_j^{\frac{1}{1-\alpha-\beta}} x_j^{\frac{\alpha}{\alpha+\beta-1}} y_j^{\frac{1-\alpha}{\alpha+\beta-1}} \tag{13}$$

and

$$y_i = \sum_j K_{ji} B_j^{\frac{1}{1-\alpha-\beta}} x_j^{\frac{1-\beta}{\alpha+\beta-1}} y_j^{\frac{\beta}{\alpha+\beta-1}} \tag{14}$$

with the world income set to 1 as the numeraire

$$1 = \sum_i B_i^{\frac{1}{1-\alpha-\beta}} x_i^{\frac{\alpha}{\alpha+\beta-1}} y_i^{\frac{\beta}{\alpha+\beta-1}}. \tag{15}$$

[15]See the online appendix of Allen et al (2014) for proof of existence and uniqueness of a general mathematical system where the GE gravity model is a member of.

Allen et al 2014 show that to solve x_i and y_i we can transform equations 13 and 14 into a general framework which has the property of having a unique fixed point. It can be shown using the Schauder's fixed point theorem that for any positive F and H, and a, b, c there exists a solution to

$$x_i = \frac{\sum_j F_{i,j} x_j^a y_j^b}{\sum_{i,j} F_{i,j} x_j^a y_j^b} \tag{16}$$

$$y_i = \frac{\sum_j H_{i,j} x_j^c y_j^d}{\sum_{i,j} H_{i,j} x_j^c y_j^d} \tag{17}$$

It can then be shown that by letting $\sum_j F_{i,j} x_j^a y_j^b = \sum_j K_{ij} B_j^{\frac{1}{1-\alpha-\beta}} x_j^{\frac{\alpha}{\alpha+\beta-1}} y_j^{\frac{1-\alpha}{\alpha+\beta-1}}$ and $\sum_j H_{i,j} x_j^c y_j^d = \sum_i B_i^{\frac{1}{1-\alpha-\beta}} x_i^{\frac{\alpha}{\alpha+\beta-1}} y_i^{\frac{\beta}{\alpha+\beta-1}}$ that (x, y) is a solution to

$$\tilde{x}_i = \frac{\sum_j K_{ij} B_j^{\frac{1}{1-\alpha-\beta}} \tilde{x}_j^{\frac{\alpha}{\alpha+\beta-1}} \tilde{y}_j^{\frac{1-\alpha}{\alpha+\beta-1}}}{\sum_{i,j} K_{ij} B_j^{\frac{1}{1-\alpha-\beta}} \tilde{x}_j^{\frac{\alpha}{\alpha+\beta-1}} \tilde{y}_j^{\frac{1-\alpha}{\alpha+\beta-1}}} \tag{18}$$

and

$$\tilde{y}_i = \frac{\sum_j K_{ji} B_j^{\frac{1}{1-\alpha-\beta}} \tilde{x}_j^{\frac{1-\beta}{\alpha+\beta-1}} \tilde{y}_j^{\frac{\beta}{\alpha+\beta-1}}}{\sum_{i,j} K_{ji} B_j^{\frac{1}{1-\alpha-\beta}} \tilde{x}_j^{\frac{1-\beta}{\alpha+\beta-1}} \tilde{y}_j^{\frac{\beta}{\alpha+\beta-1}}} \tag{19}$$

and $(s\tilde{x}, \tilde{y}) = (x, y)$ is a solution to the general equilibrium trade model where

$$s = \left(\sum_{i,j} K_{i,j} B_j^{\frac{1}{1-\alpha-\beta}} x_j^{\frac{\alpha}{\alpha+\beta-1}} y_j^{\frac{1-\alpha}{\alpha+\beta-1}} \right)^{\frac{1}{1-\frac{\alpha}{\alpha+\beta-1}}} \tag{20}$$

To satisfy the world income equation, another transformation must be made. Specifically let

$$t = \left[\sum_i B_i^{\frac{1}{1-\alpha-\beta}} (x_i)^{\frac{\alpha}{\beta+\alpha-1}} (y_i)^{\frac{\beta}{\beta+\alpha-1}} \right]^{-\frac{1-\beta}{\alpha-\beta}} \tag{21}$$

Then $(\bar{x}_i, \bar{y}_i) = \left(t^{\frac{\alpha-1}{1-\beta}} x_i, t y_i\right)$ satisfies (6) (7) and (8).[16]

[16]See Appendix A.1 of Allen et al 2014 for full proof

8.2.2 Multi Sector Case

The strategy for solving the multi sector model follows the same strategy as the single sector model found in 8.2.1. Again as in Allen et al 2014, I can redefine the system of equations in section 4.1.2 to be

$$x_i = B_i \gamma_i^{\alpha-1} (\delta_i)^{\beta}$$
$$y_i^s = (\delta_i^s)^{-1}$$
$$z_i = \prod_s \left((y_i^s)^{\theta^t} \right)^{(\alpha-\beta)}$$
$$\delta_i = \prod_t (\delta_i^t)^{\theta^t}$$

As before, we can express this system in terms of (x_i, y_i^s, z_i) by

$$\delta_i = (z_i)^{-\frac{1}{\alpha-\beta}}$$
$$\gamma_i = (B_i)^{-\frac{1}{\alpha-1}} (x_i)^{\frac{1}{\alpha-1}} (z_i)^{-\frac{\beta}{(\alpha-\beta)(\alpha-1)}}$$
$$\delta_i^s = (y_i^s)^{-1}$$

To prove that this system can be uniquely solved the constraints $\alpha, \beta \leq 0$ and $\alpha - 1 \leq \beta$. With this satisfied it can be shown that the system of equations

$$x_i = \frac{\sum_s \sum j K_{ij}^s (B_j)^{\frac{1}{1-\alpha}} (x_j)^{\frac{\alpha}{\alpha-1}} (y_j^s)^{-1} (z_j)^{\frac{\beta}{(\alpha-\beta)(\alpha-1)}}}{\sum_{i,s,j} K_{ij}^s (B_j)^{\frac{1}{1-\alpha}} (x_j)^{\frac{\alpha}{\alpha-1}} (y_j^s)^{-1} (z_j)^{\frac{\beta}{(\alpha-\beta)(\alpha-1)}}}$$
$$y_i^s = \sum j K_{ji}^s (B_i^s)^{-1} (B_j)^{-\frac{1}{1-\alpha}} (x_j)^{\frac{1}{\alpha-1}} (y_j^s)^{-1} (z_j)^{\frac{\beta}{(\alpha-\beta)(\alpha-1)}}$$
$$z_i = \prod_s \left((y_i^s)^{\theta^t} \right)^{\alpha-\beta}$$

Where

$$\sum_{i,s,j} (B_j) K_{ij}^s (B_j)^{-\frac{\alpha}{1-\alpha}} (x_j)^{\frac{\alpha}{\alpha-1}} (y_j^s)^{-1} (z_j)^{\frac{\beta}{(\alpha-\beta)(\alpha-1)}} = 1$$

8.3 Results of estimations

Table 1: Estimation results : Time of Trucking on Cost of Trucking

Variable	Coefficient (Std. Err.)
TimeToPort(hrs)	27.378^{**}
	(13.005)
Intercept	333.321^{***}
	(185.324)
N	16
R^2	0.24

Table 2: Descriptive statistics for bilateral trade flows

In Billion USD		2008	2014	Percent Change
Overall Trade				
	Agriculture	14.2	21.2	49.3
	Manufacturing	26.1	36.3	39.08
	Resources	138	153	10.8
	Total	180	239	32.78
Internal Trade				
	Agriculture	3.17	7.34	132
	Manufacturing	8.85	17.9	102.25
	Resources	11.7	17.1	46.1
	Total	23.8	42.4	78.1
Foreign Trade				
	Agriculture	11.03	14.7	33.6
	Manufacturing	17.2	18.5	7.56
	Resources	126	136	7.94
	Total	157	197	25.48

Table 3: Growth of trade flows from infrastructure changes 15 sector case

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_08_14	-1.022***	-1.870***	-0.965***	4.369***	-0.823***	-2.488***	-0.700***	3.919***
	(-4.61)	(-4.39)	(-4.27)	(4.65)	(-3.77)	(-5.96)	(-3.17)	(4.33)
DifflogSecTariff_08_14					0.299***	0.375***	0.315***	0.486***
					(15.74)	(13.16)	(16.56)	(7.12)
Adjacency/Non Adjacency	Both	Both	Non adjacent	Adjacent only	Both	Both	Non adjacent	Adjanct only
Rest of World	Yes	No	Yes	Yes	Yes	No	Yes	Yes
N	7170	3765	6135	1035	7170	3765	6135	1035
R^2	0.175	0.189	0.195	0.627	0.205	0.229	0.233	0.658

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

Table 4: Growth of trade flows from infrastructure changes 15 sectors case with 3 year averages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_avg_08_14	-0.647***	-1.357***	-0.489**	1.551**	-0.744***	-1.919***	-0.546***	0.419
	(-3.44)	(-4.62)	(-2.47)	(2.39)	(-4.06)	(-6.78)	(-2.84)	(0.67)
DifflogSecTariff_avg_08_14					0.342***	0.470***	0.325***	0.612***
					(18.83)	(17.22)	(18.31)	(8.15)
Adjacency/Non Adjacency	Both	Both	Non adjacent	Adjacent only	Both	Both	Non adjacent	Adjanct only
Rest of World	Yes	No	Yes	Yes	Yes	No	Yes	Yes
N	7170	3765	6135	1035	7170	3765	6135	1035
R^2	0.176	0.210	0.195	0.620	0.218	0.275	0.242	0.660

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 reporter-year-sector fixed effects. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 5: Growth of trade flows from infrastructure changes 15 sectors case with institution interactions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_08_14	-0.319**	-0.988***	-0.281**	-0.982***	-0.313**	-0.967***	-0.229*	-0.955***
	(-2.43)	(-4.35)	(-2.12)	(-4.36)	(-2.37)	(-4.29)	(-1.69)	(-4.26)
DifflogSecTariff_08_14	0.313***	0.301***	0.312***	0.301***	0.311***	0.301***	0.311***	0.304***
	(18.13)	(16.43)	(18.12)	(16.46)	(18.04)	(16.42)	(18.07)	(16.59)
DiffTimeIntIntRegQual	-0.631***	-0.213						
	(-3.69)	(-1.11)						
DiffTimeIntIntRuleLaw			-0.494***	-0.231				
			(-3.72)	(-1.55)				
DiffTimeIntIntPolCorr					-0.375***	-0.130		
					(-2.58)	(-0.80)		
DiffTimeIntIntPolStab							-0.480***	-0.493***
							(-3.79)	(-3.61)
FE	No	Yes	No	Yes	No	Yes	No	Yes
N	6855	6855	6855	6855	6855	6855	6855	6855
R^2	0.048	0.202	0.048	0.202	0.047	0.202	0.048	0.204

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 reporter-year-sector fixed effects. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 6: Growth of trade flows from infrastructure changes 15 sectors case with institution interactions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_08_14	-0.968***	-0.988***	-0.901***	-0.982***	-0.935***	-0.967***	-0.534**	-0.955***
	(-4.23)	(-4.35)	(-3.92)	(-4.36)	(-4.06)	(-4.29)	(-2.22)	(-4.26)
DifflogSecTariff_08_14	0.300***	0.301***	0.301***	0.301***	0.300***	0.301***	0.306***	0.304***
	(16.39)	(16.43)	(16.42)	(16.46)	(16.40)	(16.42)	(16.70)	(16.59)
DiffTimeIntRegQual	-0.0701							
	(-0.40)							
DiffTimeIntIntRegQual		-0.213						
		(-1.11)						
DiffTimeIntRuleLaw			0.154					
			(0.95)					
DiffTimeIntIntRuleLaw				-0.231				
				(-1.55)				
DiffTimeIntPolCorr					0.0437			
					(0.27)			
DiffTimeIntIntPolCorr						-0.130		
						(-0.80)		
DiffTimeIntPolStab							0.909***	
							(4.71)	
DiffTimeIntIntPolStab								-0.493***
								(-3.61)
BothRepPart	No	Yes	No	Yes	No	Yes	No	Yes
N	6855	6855	6855	6855	6855	6855	6855	6855
R^2	0.202	0.202	0.202	0.202	0.202	0.202	0.205	0.204

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 reporter-year-sector fixed effects. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 7: Growth of trade flows from infrastructure changes 3 sectors case

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_08_14	-0.721	-1.845	-1.148	4.916**	-0.513	-2.475**	-1.904	6.120***
	(-1.26)	(-1.57)	(-0.63)	(2.13)	(-0.92)	(-2.18)	(-1.11)	(2.84)
DifflogAAT_SecTariff_08_14					0.579***	0.835***	0.844***	1.467***
					(7.39)	(7.29)	(7.92)	(4.44)
Adjacency/Non Adjacency	Both	Both	Non adjacent	Adjacent only	Both	Both	Non adjacent	Adjacent only
Rest of World	Yes	No	Yes	Yes	Yes	No	Yes	Yes
N	1434	753	513	207	1434	753	513	207
R^2	0.208	0.219	0.342	0.676	0.240	0.277	0.428	0.724

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

Table 8: Growth of trade flows from infrastructure changes 3 sectors case with 3 year averages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_avg_08_14	-0.517	-1.511*	-0.992	1.672	-0.625	-2.044***	-1.246	1.056
	(-1.06)	(-1.83)	(-0.78)	(1.03)	(-1.32)	(-2.60)	(-1.06)	(0.68)
DifflogAAT_SecTariff_avg_08_14					0.671***	1.000***	0.900***	1.253***
					(9.41)	(8.67)	(8.55)	(3.66)
Adjacency/Non Adjacency	Both	Both	Non adjacent	Adjacent only	Both	Both	Non adjacent	Adjacent only
Rest of World	Yes	No	Yes	Yes	Yes	No	Yes	Yes
N	1434	753	513	207	1434	753	513	207
R^2	0.221	0.254	0.419	0.670	0.270	0.330	0.505	0.705

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

Table 9: Growth of trade flows from infrastructure changes: agriculture products

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_08_14	-0.295	-1.689	1.527	4.510	-0.112	-2.572	0.156	5.276
	(-0.29)	(-0.79)	(0.44)	(1.10)	(-0.11)	(-1.28)	(0.05)	(1.40)
DifflogAAT_SecTariff_08_14					0.609***	1.183***	1.191***	1.617***
					(4.41)	(5.47)	(5.94)	(2.78)
Adjacency/Non Adjacency	Both	Both	Non adjacent	Adjacent only	Both	Both	Non adjacent	Adjacent only
Rest of World	Yes	No	Yes	Yes	Yes	No	Yes	Yes
N	478	251	171	69	478	251	171	69
R^2	0.182	0.203	0.249	0.681	0.218	0.299	0.402	0.737

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

Table 10: Growth of trade flows from infrastructure changes: manufacturing products

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_08_14	-1.105	-2.211	-3.827	3.934	-0.949	-2.425	-3.801	5.921
	(-1.16)	(-1.11)	(-1.21)	(0.99)	(-1.01)	(-1.25)	(-1.24)	(1.57)
DifflogAAT_SecTariff_08_14					0.468***	0.534***	0.466***	1.420**
					(4.21)	(3.46)	(3.14)	(2.62)
Adjacency/Non Adjacency	Both	Both	Non adjacent	Adjacent only	Both	Both	Non adjacent	Adjacent only
Rest of World	Yes	No	Yes	Yes	Yes	No	Yes	Yes
N	478	251	171	69	478	251	171	69
R^2	0.239	0.247	0.397	0.660	0.269	0.286	0.438	0.714

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

Table 11: Growth of trade flows from infrastructure changes: Resource products

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DifflogTimeCost_avg_08_14	-0.427	-1.562	-1.884	0.661	-0.614	-2.022	-2.260	0.263
	(-0.53)	(-1.15)	(-0.88)	(0.25)	(-0.78)	(-1.55)	(-1.11)	(0.10)
DifflogAAT_SecTariff_avg_08_14					0.587***	0.800***	0.715***	0.768
					(4.85)	(4.38)	(4.00)	(1.34)
Adjacency/Non Adjacency	Both	Both	Non adjacent	Adjacent only	Both	Both	Non adjacent	Adjacent only
Rest of World	Yes	No	Yes	Yes	Yes	No	Yes	Yes
N	478	251	171	69	478	251	171	69
R^2	0.272	0.319	0.497	0.671	0.309	0.374	0.549	0.686

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

Table 12: Growth of trade flows from infrastructure changes sectors 1-5

	(1)	(2)	(3)	(4)	(5)	(6)
DifflogTimeCost_08_14	-0.965***	0.110	-0.423	-1.073	-0.836	-1.797*
	(-4.27)	(0.14)	(-0.44)	(-1.09)	(-0.77)	(-1.87)
N	6135	478	478	478	478	478
R^2	0.195	0.156	0.184	0.182	0.107	0.168

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 reporter-year-sector fixed effects. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01. Column 1 is full sample. Column 2 Animal and Animal Product, Column 3 Vegetable Products, Column 4 Foodstuffs, Column 5 Mineral Products, Column 6 Chemicals and Allied Products.

Table 13: Growth of trade flows from infrastructure changes sectors 6-10

	(1)	(2)	(3)	(4)	(5)	(6)
DifflogTimeCost_08_14	-1.022***	-1.212	-1.285**	-0.0301	-1.178	-1.706**
	(-4.61)	(-1.48)	(-1.98)	(-0.04)	(-1.45)	(-2.54)
N	7170	478	478	478	478	478
R^2	0.175	0.169	0.164	0.181	0.215	0.183

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 reporter-year-sector fixed effects. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01. Column 1 is full sample. Column 2 Plastics and Rubber, Column 3 Raw Hides, Skins, Leather and Furs, Column 4 Wood and Wood Products, Column 5 Textiles, Column 6 Footwear and Headgear.

Table 14: Growth of trade flows from infrastructure changes sectors 11-15

	(1)	(2)	(3)	(4)	(5)	(6)
DifflogTimeCost_08_14	-1.022***	-1.183	-1.684*	-1.290	-0.961	-0.784
	(-4.61)	(-1.46)	(-1.79)	(-1.52)	(-1.12)	(-1.05)
N	7170	478	478	478	478	478
R^2	0.175	0.212	0.178	0.173	0.197	0.163

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 reporter-year-sector fixed effects. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01. Column 1 is full sample, Column 2 Stone and Glass Column 3 Metals, Column 4 Machinery and Electrical, Column 5 Transportation, Column 6 Miscellaneous.

Table 15: GE single sector results

Type	alpha	beta	Coeff	StdEr	R_sq
OwnCalib	-23.00	-1.40	-0.62	0.0154	0.0819
AATCalib	-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

Coeff represents the estimated coefficient of the general equilibrium estimation. AATCalib 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).

Table 16: GE single sector results

Type	alpha	beta	theta	Coeff	StdEr	R_sq
OwnCalib Ag	-23	-1.4	-7.3449	-0.1402	0.0417	0.0476
OwnCalib Manf	-23	-1.4	-3.9976	-0.2667	0.0449	0.1768
OwnCalib Res	-23	-1.4	6.8117	-0.1105	0.0288	0.0366
AATCalib Ag	-30.2	-27.9	0	0	0	0
AATCalib Manf	-30.2	-27.9	0	0	0	0
AATCalib Res	-30.2	-27.9	0	0	0	0
EK Ag	-3.85	-3.04	0	0	0	0
EK Manf	-3.85	-3.04	0	0	0	0
EK Res	-3.85	-3.04	0	0	0	0
AL Ag	-0.67	-0.33	0	0	0	0
AL Manf	-0.67	-0.33	0	0	0	0
AL Res	-0.67	-0.33	0	0	0	0

Coeff represents the estimated coefficient of the general equilibrium estimation. AATCalib 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).

Table 17: Percent changes in trade patterns with no improvements. Universal gravity model approach

Country	Agriculture	Manufacturing	Resources
Angola	-5.706	26.687	31.577
Asia	-8.059	-9.315	-21.048
Botswana	-20.924	-48.885	-148.922
Burundi	-69.469	-57.687	-1.402
Congo; Dem. Rep.	-65.950	-99.861	-70.867
EU27	-4.166	6.178	-6.112
Kenya	-37.616	-3.090	-0.688
Lesotho	-68.983	-61.466	-93.272
Malawi	-36.206	-58.181	-89.398
Mozambique	8.952	-18.060	-48.307
Namibia	33.189	12.055	-1.645
North America	-14.624	-7.092	12.633
Rest of Africa	-25.700	2.259	-0.737
Rwanda	-61.007	-19.884	-13.904
South Africa	31.714	39.401	44.396
South America	-16.944	-3.129	-8.952
Swaziland	-7.462	-75.772	-70.793
Tanzania	-21.383	0.651	-13.371
Uganda	5.040	12.043	18.453
Zambia	-12.386	-17.325	-90.601
Zimbabwe	7.110	16.562	23.206
Mean	-18.599	-17.329	-26.179

Table 18: Percent changes in trade patterns with no improvements: for internal and foreign trade. Universal gravity model approach

Country	Intertrade Agriculture	Intertrade Manufacturing	Intertrade Resources	Foreign trade Agriculture	Foreign trade Manufacturing	Foreign trade Resources
Angola	6.987	17.808	6.630	-12.697	67.947	11.576
Asia	-0.935	0.368	-12.485	-7.128	-35.293	-9.633
Botswana	-27.980	-217.147	-284.683	7.046	21.949	-51.684
Burundi	-53.778	-47.321	16.332	-15.717	-63.342	-19.122
Congo; Dem. Rep.	-54.293	-92.456	-46.673	-11.698	-59.914	0.300
EU27	-0.018	1.344	-6.650	-4.144	32.638	-5.467
Kenya	-35.678	-7.517	-2.813	-1.953	-2.269	1.650
Lesotho	-69.170	-172.298	-42.737	0.152	-9.927	-0.046
Malawi	-27.274	-44.916	-43.398	-8.878	-87.015	-13.844
Mozambique	9.109	-19.620	10.452	-0.152	-16.766	-39.365
Namibia	28.917	50.730	-33.119	4.269	2.549	25.461
North America	-0.133	1.002	15.632	-14.486	-63.760	12.777
Rest of Africa	-0.415	1.094	2.704	-25.297	4.234	-6.166
Rwanda	-39.523	-12.761	-13.191	-21.492	-22.521	-3.957
South Africa	2.912	-7.027	55.898	28.778	224.356	45.453
South America	-0.122	-0.586	15.212	-16.829	-40.659	-43.681
Swaziland	-10.101	-154.019	-24.749	2.640	-22.101	-12.691
Tanzania	-19.742	-38.403	-8.819	-1.653	40.955	-7.774
Uganda	7.975	13.606	20.212	-2.933	19.729	6.781
Zambia	-8.780	-16.605	-407.076	-3.610	-104.581	-6.532
Zimbabwe	4.052	9.303	53.735	3.065	28.698	-29.944
Mean	-13.714	-35.020	-34.742	-4.891	-4.052	-6.948

Table 19: Percent changes in trade patterns with no improvements. Fixed effects estimation approach

partner	**Agriculture**	**Manufacturing**	**Resources**
Angola	-.7562943	-3.850906	-2.656377
Asia	-.7998352	-2.991833	-2.063786
Botswana	-.4234428	-2.131882	-1.470589
Burundi	-2.351665	-8.869926	-5.612923
Congo, Dem. Rep.	-1.629259	-7.39006	-5.097706
EU27	-.8119984	-3.037334	-2.095171
Kenya	-1.487454	-5.563925	-3.838028
Lesotho	-.0723481	-.9412994	-.7331028
Malawi	-.6521988	-3.274132	-1.682848
Mozambique	-.8179779	-3.059692	-1.939945
Namibia	-.8631516	-3.22868	-2.227158
North America	-.893898	-3.343687	-2.306496
Rest of Africa	-2.732956	-10.61326	-7.321087
Rwanda	-1.772747	-7.387501	-4.016689
SADCEAC Mainland	-.6009445	-2.247875	-1.550598
South Africa	-.4602509	-1.721603	-1.187569
South America	.5443211	2.356504	1.625526
Swaziland	-.4585228	-2.058716	-1.183109
Tanzania	-1.675613	-6.384274	-4.403908
Uganda	-1.907572	-7.985739	-5.326363
Zambia	-.5795517	-2.272041	-1.567268
Zimbabwe	-.4018288	-1.641863	-1.4287
Total	-.9820541	-3.983624	-2.640177

Table 20: Percent changes in trade patterns with no improvements: for internal and foreign trade. Fixed effects estimation approach

Partner	Internal_Ag	Internal_Manf	Internal_Res	Foreign_Ag	Foreign_Manf	Foreign_Res
Angola	-.2577457	-1.986057	-1.369992	-.4985476	-1.864851	-1.286385
Asia	.	.	.	.	.	.
Botswana	-.3575249	-1.885319	-1.300503	-.065918	-.2465668	-.170084
Burundi	-1.568172	-5.93923	-3.830353	-.7834892	-2.930696	-1.78257
Congo, Dem. Rep.	-.8529358	-3.934719	-2.714191	-.7763243	-3.45534	-2.383513
EU27	.	.	.	.	.	.
Kenya	-1.081184	-4.044243	-2.789742	-.4062703	-1.519682	-1.048285
Lesotho	-.0371063	-.4893494	-.3851852	-.0352421	-.451952	-.3479176
Malawi	-.2058449	-1.604511	-.5311356	-.4463539	-1.669619	-1.151712
Mozambique	-.3898544	-1.458267	-.8352699	-.4281235	-1.601425	-1.104673
Namibia	-.4617844	-1.727341	-1.19153	-.4013662	-1.501338	-1.035632
North America	.	.	.	.	.	.
Rest of Africa	.	.	.	.	.	.
Rwanda	-1.236931	-5.383232	-2.634136	-.5358162	-2.004263	-1.382553
SADCEAC Mainland	.	.	.	.	.	.
South Africa	-.4712715	-1.762817	-1.216	.0110168	.0412178	.0284309
South America	.	.	.	.	.	.
Swaziland	-.2415409	-1.247074	-.6232376	-.2169828	-.8116398	-.5598736
Tanzania	-.907486	-3.511038	-2.421936	-.7681284	-2.873238	-1.981976
Uganda	-.8951855	-4.198835	-2.714133	-1.012387	-3.786903	-2.612228
Zambia	-.7256813	-2.818649	-1.944321	.1461296	.5466061	.3770514
Zimbabwe	-.5953135	-2.36561	-1.927945	.1934857	.7237465	.4992446
Total	-.6428476	-2.772268	-1.776851	-.3765198	-1.462871	-.9964173

Table 21: Percent changes in trade patterns with modern ports. Universal gravity model approach

Country	Agriculture	Manufacturing	Resources
Angola	10.549	14.381	2.830
Botswana	0.858	10.916	21.063
Burundi	8.061	23.118	4.311
Congo; Dem. Rep.	7.233	12.602	1.829
Kenya	4.209	8.493	2.538
Lesotho	-0.013	-0.043	-0.054
Malawi	2.233	12.300	2.107
Mozambique	1.888	-0.809	-0.937
Namibia	0.111	-3.305	-1.773
Rwanda	3.811	8.096	1.107
South Africa	3.584	6.610	2.208
Swaziland	0.730	3.807	0.909
Tanzania	2.451	-1.124	0.640
Uganda	8.468	19.438	5.180
Zambia	5.981	129.935	10.625
Zimbabwe	3.365	16.609	8.631
Mean	2.854	6.036	1.952

Table 22: Percent changes in trade patterns with modern ports: for internal and foreign trade. Universal gravity model approach

Country	Intertrade Agriculture	Intertrade Manufacturing	Intertrade Resources	Foreign trade Agriculture	Foreign trade Manufacturing	Foreign trade Resources
Angola	0.022	0.081	0.006	11.136	15.131	3.096
Botswana	0.091	0.625	0.201	0.948	12.581	25.007
Burundi	-0.032	0.028	-0.016	13.699	39.165	2.342
Congo; Dem. Rep.	0.029	0.063	-0.061	11.981	20.863	2.645
Kenya	-0.051	-0.019	-0.018	5.845	11.712	0.643
Lesotho	-0.110	-0.072	-0.107	0.088	0.000	-0.016
Malawi	-0.094	-0.084	-0.126	3.131	16.813	2.011
Mozambique	-0.014	-0.007	-0.021	1.734	-0.730	-1.063
Namibia	-0.030	-0.024	-0.287	0.104	-2.184	-0.873
Rwanda	-0.032	0.025	0.025	6.170	13.011	0.504
South Africa	-0.018	-0.024	-0.376	2.463	4.534	1.336
Swaziland	-0.065	-0.091	-0.094	0.850	4.181	1.039
Tanzania	-0.016	0.044	-0.001	2.993	-1.409	-0.127
Uganda	-0.032	0.006	-0.004	8.075	18.456	0.892
Zambia	-0.019	0.019	-1.282	6.743	146.061	8.951
Zimbabwe	-0.077	-0.078	-0.131	3.205	15.519	7.973
Mean	0.050	0.090	0.256	3.506	7.602	0.621

Table 23: Percent changes in trade patterns with China ports. Fixed effects estimation approach

partner	**Agriculture**	**Manufacturing**	**Resources**
Angola	.624897	2.744604	1.621319
Asia	3.883907	17.05847	10.07694
Botswana	1.11517	4.897926	2.893349
Burundi	.9830513	4.317654	2.155329
Congo, Dem. Rep.	.8538494	4.427891	2.615686
EU27	3.455116	15.17519	8.964428
Kenya	.7440062	3.267742	1.930351
Lesotho	.3224583	2.031525	1.034834
Malawi	.7831078	3.439484	2.031803
Mozambique	.1089592	.4785614	.2826996
Namibia	.1458263	.6404877	.3783531
North America	3.238359	14.22317	8.402042
Rest of Africa	2.849457	13.00809	7.684261
Rwanda	.6336555	2.783077	1.644047
South Africa	.5210037	2.288292	1.351765
South America	2.271095	10.34111	6.108795
Swaziland	.5989227	2.630524	1.553928
Tanzania	.1362267	.5983276	.353447
Uganda	.9239635	4.058136	2.397261
Zambia	1.344063	5.903244	3.487217
Zimbabwe	1.142951	5.019941	2.965426
Total	1.277108	5.711425	3.348196

Table 24: Percent changes in trade patterns with China ports: for internal and foreign trade. Fixed effects estimation approach

partner	**Internal_Ag**	**Internal_Manf**	**Internal_Res**	**Foriegn_Ag**	**Foriegn_Manf**	**Foriegn_Res**
Angola	0	0	0	.624897	2.744604	1.621318
Asia	.	.	.	.	.	.
Botswana	0	0	0	1.11517	4.897928	2.893349
Burundi	0	0	0	.9830513	4.317653	2.155332
Congo, Dem. Rep.	0	0	0	.8538489	4.427893	2.615687
EU27	.	.	.	.	.	.
Kenya	0	0	0	.7440062	3.267742	1.930351
Lesotho	0	0	0	.3224578	2.031525	1.034834
Malawi	0	0	0	.7831087	3.439482	2.031804
Mozambique	0	0	0	.1089611	.4785652	.2827024
Namibia	0	0	0	.1458278	.6404872	.378355
North America	.	.	.	.	.	.
Rest of Africa	.	.	.	.	.	.
Rwanda	0	0	0	.6336555	2.783078	1.644046
South Africa	0	0	0	.5210037	2.288292	1.351762
South America	.	.	.	.	.	.
Swaziland	0	0	0	.5989227	2.630525	1.553928
Tanzania	0	0	0	.1362286	.5983257	.3534489
Uganda	0	0	0	.9239645	4.058137	2.397261
Zambia	0	0	0	1.344063	5.903243	3.48722
Zimbabwe	0	0	0	1.142951	5.019941	2.965427
Total	0	0	0	.6863823	3.095464	1.793552