ESSAYS IN TRADE AND DEVELOPMENT

Alexander Pearson

A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Economics.

Chapel Hill
2018

Approved by:

Simon Alder

Patrick Conway

Anusha Chari

Lutz Hendricks

Toan Phan

ABSTRACT

ALEXANDER PEARSON: Essays in Trade and Development.
(Under the direction of Simon Alder)

My dissertation focuses on the spatial aspects of trade and development. The first chapter 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.

The second chapter analyzes the effect of nine resource commodities on economic growth at the sub-national level. Combining georeferenced data on resource locations with satellite data on night lights, I estimate the causal effect of resources on district-level growth between 1992 and 2013, using exogenous variation in the value of a mine due to changes in the world price of the corresponding commodity. I find that districts that are resource-abundant grow more slowly than other districts in the country. However, relatively faster growth in resource-abundant districts is observed in the following 5 years from the initial year of a price increase. Furthermore, I estimate the spillover effects of resource-abundant districts within their state and find large spillover effects not only on adjacent districts, but also on large cities. Finally, I analyze the role of institutions for the distributional impact of mining regions. I find that the specific regions that benefit from mining activity change given the institutional characteristics and revenue sharing policies of the country.

Amanda, thank you for your constant love and support. You have helped me become a better person in countless ways for which I am forever grateful for.

To my loving parents, Ronald and Kimberley Pearson, whose hard work and compassion influenced me greatly. Thank you for your lifelong faith in me.

ACKNOWLEDGMENTS

I would like to thank my advisor, Simon Alder, whose guidance, support and kindness were paramount to my work at the University of North Carolina at Chapel Hill.

I would like to thank my thesis committee members, Patrick Conway, Anusha Chari, Lutz Hendricks, and Toan Phan, for all their valuable feedback through this process. I am also grateful for all the comments from participants at the UNC Macroeconomics Workshop.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

WHY DON'T AFRICAN COUNTRIES TRADE MORE WITH EACH OTHER? THE ROLE OF BORDER CROSSINGS IN GENERAL EQUILIBRIUM

1.1 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, a much lower percentage than in 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

[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.

times, on bilateral trade flows and analyzes their significance to regional integration in a general equilibrium trade model. I focus 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 were introduced 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

[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.

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.

1.2 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) provide 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.

[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 accounting 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.

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 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 (2016) 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 (2018) 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.

1.3 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 2014.[7] I use the two-digit product classification, leading to 97 different product types. I use import data since import data tends to be more accurate than compared to export data due to the fact that imports are more likely to be taxed.[8] Some countries did not report trade flows in 2008. For these countries, I use the export data from other countries that did report to approximate their imports. For trade with the rest of the world I combine countries into five

[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.

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

[8]See World Bank 2010.

groups: North America, 27 countries of the European Union, Asia, South America, and the rest of Africa. Appendix Table A.1 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.

1.3.1 Multi Modal Transportation

Several papers forgo the inclusion of interactions that are outside of the study area.[9] 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 change one's result significantly. 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.[10] In order to include the transportation network with the rest of the world, costs

[9] 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.

[10] 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.

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.[11] 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.

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.

1.4 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.[12] 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-sector and exporter-sector fixed effects between 2008 and 2014 where all of the surveys and improvements were implemented. Let

$$\Delta \ln X_{ij}^{s} = \mu \Delta \ln T_{ij} + \beta_1 \Delta \mathbf{Z_{ij}} + \gamma_{\mathbf{is}} + \delta_{\mathbf{js}} + \epsilon_{\mathbf{ij}} \tag{1.1}$$

where X_{ij}^{s} are trade flows from i to j in sector S, T_{ij} is the sum of all border waiting times that i and

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

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

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 partner is overseas.[13]

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.[14]

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 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

[13] 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.

[14] 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.

$$\Delta \ln T_{ij} = \alpha_1 \Delta \ln B_c + \psi_i + \phi_j + \nu_{ij} \tag{1.2}$$

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

$$\Delta X_{ij}^s = \beta_1(\hat{\alpha_1} \Delta \ln B_c + \hat{\psi}_i + \hat{\phi}_j) + \Delta \mathbf{Z_{ij}} + \gamma_{\mathbf{is}} + \delta_{\mathbf{js}} + \epsilon_{\mathbf{ij}} \tag{1.3}$$

where $\hat{\alpha_1} \Delta \ln B_c + \hat{\psi}_i + \hat{\phi}_j = \Delta \ln \hat{T}_{ij}$ is the predicted values from (1.2).

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 Appendix Table A.2, 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. Appendix Table A.3 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 1.1 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

$$\Delta \ln X_{ij}^{s} = \mu^{s} \Delta \ln T_{ij} + \beta_1 \Delta \mathbf{Z^s_{ij}} + \gamma^{\mathbf{s}}_{\mathbf{i}} + \delta^{\mathbf{s}}_{\mathbf{j}} + \epsilon^{\mathbf{s}}_{\mathbf{ij}} \tag{1.4}$$

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.[15]

1.4.1 Gravity Equation Estimation Results

To see how border wait times affect trade flows following the specification in equation 1.1, I begin with the 15-sector case excluding the rest of the world. This baseline result is shown in Table 1.1. 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

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

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.

The estimates found for the effects of changes in the aggregate tariff rate on the change of trade flows are reported to be positive. There are a number of potential ways to explain this counter-intuitive result. First, by 2008 tariffs were eliminated for all non-sensitive products. Once the minimum requirements were met for the non-sensitive products, products on the sensitive list were required to be reduced as well. Many of these particular products took longer to become duty free therefore, for these sensitive products, it could be the case that the products expected not to be imported as often, were the easier products to reduce tariff rates on. Additionally, the products that were expected to increase in imports in the future could give governments an incentive to maintain tariffs at high levels for those products. Second, Pelikan and Brockmeier (2008) show how using weighted aggregate tariffs can lead to endogeneity issues that underestimate the effects of tariffs. As tariff rates increase and the number of imports subsequently goes down, the actual change in tariff rates will be smaller due to the weight of that product decreasing. Finally, many of the tariffs still in place may be over products that report zero imports. This eliminates the observation from the standard regression along with the information that high tariffs reduced the imports of that product (to zero).

Appendix Table A.4 incorporates trade with the rest of the world and includes a control for port costs. 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 1.2 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

Table 1.1: 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.

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 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.

Appendix Tables A.5, A.6 and A.7 show estimates for equation 1.4, 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 Appendix Table A.8, 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 many 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

Table 1.2: 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.

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.

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 1.3 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 1.3: 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.

1.4.2 Measure of Combined Transportation Cost

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.

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. Appendix Table A.9 converts each hour of waiting into 43.75 USD and Appendix Table A.10 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.

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. Appendix Table A.11 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. Appendix Table A.12 shows similar magnitudes to those found in Appendix Tables A.9 and A.10 which were derived from the ad valorem estimate.

1.4.3 Robustness Exercises

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 1.1 but hold constant the route used for travel. Appendix Table A.13 shows the new results and Appendix Table A.14 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.

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. Appendix Table A.15 reports the estimates to the specifications made in Table 1.1 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.

Trade Flow Measures

When import data are not available between two trading partners but export data are available from the other reporter, I assume that the amount of trade that occurred was equal to the export data of the other reporter. Appendix Table A.16 uses data only for imports and records zero even if the respective trading partner's export data contradicts the import data. Appendix Table A.17 exclusively uses export data. Since more zeros are recorded, Appendix Table A.18 uses the PPML estimator with import data exclusively which allows for zero trade flows. Appendix Table A.19 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 and obtain similar results.[16]

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. Appendix Table A.20 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.

1.4.4 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.

1.5 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.

1.5.1 Model Setup

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

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 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

[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).

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

$$X_{ij}^s = K_{ij}^s(\gamma_i)(\delta_j^s). \tag{1.5}$$

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 $i \in S$

$$\sum_j X_{j,i}^s = B_i^s Y_i. \tag{1.6}$$

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 $i \in S$

$$\sum_s \sum_j X_{i,j}^s = Y_i. \tag{1.7}$$

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 $i \in S$

$$Y_i = B_i \gamma_i^{\alpha} \left(\prod_s (\delta_i^s)^{\theta^s} \right)^{\beta} \tag{1.8}$$

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.[18] 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

$$\sum_i Y_i = 1. \tag{1.9}$$

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.

[18]In the Armington model (Armington 1969) Bi would be characterized by population and total factor of productivity for country i. My main specification in the proceeding sections uses this same strategy.

The addition of multiple sectors follows the same method as the single sector case above.[19] 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

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

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.[20]

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:

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

[20] Specifically:

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

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

$$= X_{ij}^{s}(A_{l,i}^{+} + A_{l,N+j}^{+}) + (A_{(s^{'}N+l),i}^{+} + A_{(s^{'}N+l),N+j}^{+})) - 2c_{ij}^{s}$$

and income changes for country l is defined by.

$$\frac{\partial lnY_l}{\partial ln K_{ij}^{s}} = \alpha \frac{\partial ln\gamma_l}{\partial ln K_{ij}^{s}} + \beta \sum_{s^{'}} \theta^{s^{'}} \frac{\partial ln\delta_l^{s^{'}}}{\partial ln K_{ij}^{s}} =$$

$$X_{ij} \times (\alpha(A_{l,i}^{+} + A_{N+l,j}^{+} + c_{ij}^{s}) + \beta \sum_{s^{'}} \theta^{s^{'}} (A_{(s^{'}N+l),i}^{+} + A_{(s^{'}N+l),N+j}^{+} + c_{ij}^{s})$$

1.5.2 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 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.

$$(\alpha^{*}, \beta^{*}, \theta_1^{*}, \ldots, \theta_s^{*}, \mu^{1*}, \ldots, \mu^{s*}) = arg \min_{\alpha,\beta \in \mathbb{R}, \mu \in \mathbb{R}^{S}}$$

$$\sum_{s} \sum_{i} \sum_{j} \left(\ln \hat{X_{ij}^{s}}^{observed} - \ln \hat{X_{ij}^{s}}^{predicted} \right)^2. \qquad (1.10)$$

As in Allen et al (2014) the method used to calibrate $(\alpha^{*}, \beta^{*}, \theta_1^{*}, \ldots, \theta_s^{*}, \mu^{1*}, \ldots, \mu^{s*})$ 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

$$(\alpha^{*}, \beta^{*}, \theta_1^{*}, \ldots, \theta_s^{*}, \mu^{1*}, \ldots, \mu^{s*}) = arg \min_{\alpha,\beta \in \mathbb{R}, \mu \in \mathbb{R}^{S}}$$

$$\sum_s \sum_i \sum_j \left(\ln \hat{X}_{ij}^{s\ o} - \hat{T'}^{s}_{ij}\mu - \ln \hat{\gamma}_i\big(\hat{T}\mu;\alpha,\beta,\theta\big) - \sum_s \ln \hat{\delta^s}_j\big(\hat{T}\mu;\alpha,\beta,\theta\big)\right)^2 \tag{1.11}$$

where

$$\ln \hat{\delta^s}_j\big(\hat{T}\mu\big) \approx \sum_{s'} \sum_k \sum_l \frac{\partial \ln \hat{\delta}_j^s}{\partial \ln \hat{K}_{kl}^{s'}} \hat{T}_{kl}^s \mu^s \tag{1.12}$$

and

$$\ln \hat{\gamma}_i\big(\hat{T}\mu\big) \approx \sum_{s'} \sum_k \sum_l \frac{\partial \ln \hat{\gamma}_i}{\partial \ln \hat{K}_{kl}^{s'}} \hat{T}_{kl}^s \mu^s. \tag{1.13}$$

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 1.11 can be written as

$$\mu(\alpha,\beta,\theta_1,\dots,\theta_s) =$$
$$\left(\big(\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}}\big)'\big((\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}}\big)\right)^{-1}\big(\boldsymbol{D}(\alpha,\beta)\hat{\boldsymbol{T}})\big)'\hat{\boldsymbol{y}} \tag{1.14}$$

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 $\frac{\partial ln X_{ij}^s}{\partial K_{kl}^s}$, and $\hat{\boldsymbol{y}}$ denotes the $N^2 \times 1$ vector whose $\langle i + j(N-1)\rangle$ row is $ln\hat{X}_{ij}^{s\ o}$.

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

$$\ln \hat{X}_{ij}^s = (\hat{T^s}_{ij}^{GE})'\mu^s + \epsilon_{ij}^s \tag{1.15}$$

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

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

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

$$(\alpha^*, \beta^*, \theta_1^*, \ldots, \theta_s^*) =$$
$$arg \min_{\alpha,\beta \in \mathbb{R}} \hat{\boldsymbol{y}} \Bigg(\boldsymbol{I} - \hat{\boldsymbol{T}} \Bigg(\big(\boldsymbol{D}(\alpha, \beta) \hat{\boldsymbol{T}} \big)' \big((\boldsymbol{D}(\alpha, \beta) \hat{\boldsymbol{T}} \big) \Bigg)^{-1} \big(\boldsymbol{D}(\alpha, \beta) \hat{\boldsymbol{T}}) \big)' \Bigg) \hat{\boldsymbol{y}}. \tag{1.16}$$

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.

1.5.3 General Equilibrium Calibration Estimation Results

Table 1.4 shows the results for equation 1.15 with various gravity constants of alpha and beta. Row 1 shows estimates when minimizing equation 1.14 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 to 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 1.4: 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 for μ represent the estimated coefficients of the general equilibrium estimation given various values of the gravity constants. AAT Calibration 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 Appendix Table A.21 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 A.1 shows the R-squared values of the general equilibrium estimation over combinations of different parameters. We see that there are clear local maxima with a smooth increase in R-sqaured to the calibrated parameter values.

1.6 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.

1.6.1 No Border Improvements

Appendix Table A.22 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 1.5 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 1.5: Percentage point change in trade patterns with no improvements: for internal and foreign trade. Universal gravity model approach

Country	Internal trade Agriculture	Internal trade Manufacturing	Internal trade 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

Table shows the percentage point difference in the growth of trade flows between the counter-factual scenario of no border improvements and the observed growth in trade from 2008 to 2014.

1.6.2 Efficient Border Crossings

Next, I create a hypothetical scenario in which border waiting times are reduced to 3-hours, similar to that between OECD countries who have established border crossings. Appendix Tables A.23 and A.24 show 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.

1.6.3 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, Appendix Table A.25 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, Appendix Tables A.26 and A.27 show 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.

1.7 Conclusion

It has been argued previously 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 interdependence 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 but 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.

I find 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 comparing reduced form versus general equilibrium results, including certain trading partners like the outside world and incorporating multi-modal transportation networks. 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.

CHAPTER 2

THE EFFECT OF COMMODITY PRICES AND MINES ON SPATIAL DEVELOPMENT: EVIDENCE FROM SATELLITE DATA

2.1 Introduction

The growth of large economies like China can have a significant impact on resource abundant countries due to their increasing demand for raw materials that are used to build manufactured goods and large-scale infrastructure projects. For instance, iron ore production tripled between 1992 and 2013, and at the same time, real prices went from 33 USD per dry metric ton (dmtu) in 1992 to 151 USD/dmtu in 2008 before coming down again to 127 USD/dmtu in 2012. Local and national governments that are endowed with an abundance of resources are naturally interested in the regional effects that large commodity price increases will bring. However, whether resource abundance fosters economic development or leads to a resource curse, particularly at a subnational level, is still being debated with no clear consensus.[1]

This paper provides a new approach to measuring the effects of resource abundance and mining activity on economic development, by exploiting both between and within-country variation, a task that has been difficult due to data constraints. Looking at district level growth and district-specific resource abundance gives insights on where the effects are being felt within the country. In addition to this, looking at over 100 countries then allows for the control of country- and time-specific non-observables, which cannot be done when studying a single country. This allows me not only to determine whether mining districts benefit or not from the mining activity, but also determine which regions in the country are benefiting from the additional revenues at a multi-country level.

Since income data are rarely collected at a subnational level for many countries that are of interest, I use night-time luminosity data from 1992 to 2013, which has been demonstrated to be an adequate alternative to

[1] Abubakr et al. (2017) provides a 'survey of surveys' of the literature that concludes that the evidence for the resource curse is convincing whereas John (2011) provides a similar survey that reaches a different conclusion.

measuring GDP growth when other data is not available (Henderson et al. 2012). In order to quantify the resource abundance of a district, I use spatial data from the United States Geological Survey (USGS) that has surveyed 305,000 different resource locations worldwide documenting size, type of resource, operational activity and ownership. Using exogenous world pricing data from the World Bank Commodity Market Outlook's (CMO) dataset, I then estimate the interaction effects of prices and resource abundance on yearly night-time luminosity. Controlling for country-year and district fixed effects, I find that districts with high mining activity tend to grow more slowly than other districts after an initial price increase. However, subsequent periods show an increase in economic activity within the mining district from the initial price increase for up to five years. A one standard deviation in a price increase leads to an estimated .95 percentage points slower growth for the mining districts for the initial year. However, mining districts see an average of .92 percentage points faster growth in development for the following 4 years after the initial price increase. Taking advantage of the spatial nature of the data, I measure the spillover effects of mining and resource abundant locations on other locations. I find that districts adjacent to mining areas and large cities located within the same state saw similar responses to world price changes as the mining districts, suggesting that cities in resource-rich states depend, to a certain degree, on mining activity in the state for additional growth.

I then determine the role of institutional characteristics and conflict on both the impact on mining districts and the distributional effects that mining locations have on their states from exogenous world prices. I find that low corruption and high rule of law mitigate the slow growth seen initially and accelerates the growth in subsequent years when world prices increase. In addition, higher levels of external conflict also increased the long-term development of these districts. To analyze the role of institutional characteristics on the distribution of development due to mining activity within a state, I estimate separate responses for four groups of countries that represent different institutional qualities by using a clustering method for bureaucratic quality, corruption and rule of law measures.[2] I find that countries that have higher bureaucratic quality, low corruption and higher rule of law distribute the effects of mining activity throughout the state. Countries that exhibit weak institutional characteristics see state administrative capitals grow faster than average when world prices increase. I conduct a similar analysis using three conflict measures: internal conflict, external conflict and ethnic tensions. I find that countries with high internal conflict and ethnic tension, but low levels of external conflict see districts within mining states have negative spillover effects

[2]See Sumner and Vazquez (2014) for a similar methodology to classify developing countries over time using economic development, human development, better governance, and environmental sustainability indicators.

on growth when prices increase.

Finally, in order to look more closely at policies that determine where mining revenue is spent, I focus on three proximate countries, Chile, Argentina and Brazil, who have remarkably different resource revenue sharing policies. The analysis shows significant differences in the distributional effects of mining activities that correspond to the country's overall revenue sharing arrangements and government structure.

The organization of this paper is as follows: The next section provides a brief review of the literature related to this paper. Section 3 will discuss the data used while section 4 provides the empirical strategy. Section 5 describes the results, section 6 provides the case study of Chile, Argentina and Brazil, and section 7 concludes.

2.2 Literature Review

The question of whether an area's resource endowment helps or hinders its development has been debated already in Adam Smith's Wealth of Nations in which, talking about the development of mines, he says a "...prudent lawgiver, who desired to increase the capital of his nation, would least choose to give any extraordinary encouragement, or to turn towards them a greater share of that capital than that would go to them of its own accord."[3] In recent years the idea again became popular with the work of Sachs and Warner (1995, 2001) who showed that countries that had higher resource dependency as a fraction of their GDP would have lower growth than those with lower resource dependence. Similar results were shown by Engerman et al. (1997), Sala-i-Martin et al. (2004), Melhum et al. (2007) and Humphreys et al. (2007). However, a growing amount of literature has come out arguing against the idea of resource endowment being a curse to the economy. Manzano and Rigobon (2007) provide two issues that they find in the resource curse literature. First, if using a cross-section of the data, individual country characteristics that may be unobserved could be correlated with the independent variables leading to biased estimates. They provide a two-time-period and four-time-period panel data set to control for country fixed effects and find that the negative effects of

[3] Adam Smith's mention is considered the first to be recorded discussing this issue. More recently, theories for resources causing harm to an economy were stated by Watkins (1963), Corden and Neary (1982) and Auty, R. (1993).

resources disappear.[4] Second, GDP, which is what the majority of these studies use as their dependent variable, includes the resource sector that can create a misleading relation between resource endowments and growth. Brunnschweiler and Bulte (2008) also note that using resource dependency, measured by exports of resources over total GDP, leads to endogeneity issues, and using stock-based measurements of resources would be superior.

More recently, studies have been analyzing how the resource curse can affect regional development using individual countries with, again, conflicting results. Papyrakis and Gerlagh (2007) find that natural resource abundance decreases local investment, schooling, and openness when looking at American states. Ivanova (2014), looking at regions in Queensland Australia, found that the majority of revenue obtained from mining would go to other major metropolitan areas and, in some places, reduce diversification and forward and backward linkages to other regions. There has also been evidence, however, that resource endowments actually benefit local regions. Michaels (2011) finds that regions in the southern states of the U.S. that had large amounts of oil reserves had higher growth and increased manufacturing employment along with better infrastructure. Domenech (2008) showed that regions in Spain were benefited in regards to industrialization from having higher values of mineral endowments between 1860 and 1936. One negative aspect of looking at regional development within a single country is that the results are difficult to apply to other countries due to country-specific observable and unobservable characteristics.[5] This paper will allow for both country-time varying unobservables while still analyzing development changes at a local level for all countries. The estimation strategy used in this paper follows closely to those found in Berman et al. (2017), who look at 50km by 50km regions in Africa and analyze the effects of mineral activity, interacted with world prices, on various conflict measures.

Another related field is the literature on the impacts of short-run demand shocks on country and regional development. Examples include Black et al. (2005), who look at the boom, peak and bust of the coal mining

---

[4] Manzano and Rigobon (2007) are unable to add more time elements due to data constraints for the majority of countries. Collier and Goderis (2012) also provide a panel data approach and find short-term gains and long-term losses from non-agriculture commodities. However, Collier and Goderis (2012) run into the endogeneity problem of having the dependent variable being a function of resource shares.

[5] There are several more benefits to looking at single country cases that help disentangle some of the mechanisms behind how resource endowments affect regional development that this paper has to abstract from. For instance, Borge, Parmer and Torvik (2015), observing resource revenue to local governments from hydropower in Norway, found that regions with higher hydro revenue had less efficiency in producing public goods a term they call the paradox of plenty, but did not find evidence that the revenue from hydropower was any less efficient than other revenue sources such as taxes.

industry in four U.S. states, finding positive spillover effects to other districts, but no evidence of negative spillover effects. Addison et al. (2014) look at commodity pricing shocks in 14 Sub Saharan African countries and estimate, using vector autoregressions, the asymmetric response that prices could have on per capita incomes. Little evidence was found that either unexpected increases or decreases in commodity prices affected per capita income. Collier and Goderis (2012) also use vector autoregression models on a larger sample and longer time period (45 years) and find that positive commodity price shocks have short-term benefits and long-term negative consequences at the country level.

Finally, this paper is also related to a large body of literature that estimates the effects of institutional characteristics and the degree of conflict on economic development, particularly when countries are resource abundant. Mehlum et al. (2006) show that institutions play a significant role in countries falling into the resource curse. Bazzi and Blattman (2014) provide a survey of the various channels in which resource abundance of an area can increase the probability of conflict.

2.3 Data

In order to analyze the effects of mining activity both between and within countries, a combination of spatial and country level data is needed. This section details the specific data needed for this analysis.

2.3.1 Mining Data

As mentioned in the preceding section, using resource income as an explanatory variable to explain economic growth can lead to endogeneity issues. However, using stock measures for resource abundance mitigates this problem as suggested by Brunnschweiler and Bulte (2008). Therefore, to identify each district's resource abundance, I use the United States Geological Survey's (USGS) Mineral Resource Data System (MRDS) that contains 305,000 different resource locations around the world (USGS 2005). These locations are broken down into over 30 different commodities and provide details on whether the area was a past producer, current producer, occurrences not yet actively mined upon, and refining locations. Mines are also, when available, classified into three different production sizes; small, medium or large.[6] For this

[6] Although the specific amounts are not readily available for mines over the sample period, quantities were recorded for some past producers. I find that iron production of small mines amounts to 414528 metric tons (mt), 1,012,110 mt for medium mines and 3,608,952 mt for large mines.

study, I include nine mineral resources: iron, copper, aluminum, tin, zinc, nickel, coal, gold, and silver. [7] In order to track the economic impact these mines have over time, I use exogenous world prices for each commodity from the World Bank Commodity Market's (CMO) pink sheet. These provide averaged annual data on various resource commodities in real dollars.

2.3.2 Administrative Areas

To capture administrative areas within each country, I use the Global Administrative Areas (GADM) shapefile for the entire world. These administrative areas are organized by country, state, and district/county. For this analysis, I use the district/county administrative area which allows me to use country-year fixed effects in order to account for country- and time-specific unobserved heterogeneity. To identify key districts within each state, I use Natural Earth and Esri's world populated area datasets. These identify country level capitals, state-level capitals and large populated cities within each district. Of the 256 countries and entities in the dataset, 120 report mining and resource locations within their borders.

Table 2.1: Descriptive Statistics: District Level

	Observations	Mean	Standard deviation	Median
Sum of night light (ln)				
all districts	1,033,032	6.508	2.688	6
if mines >0	49,148	7.693	2.708	8
if mines = 0	983,884	6.449	2.673	6
Annual growth of night light (%)				
all districts	939,120	7.82	7.47	5.42
if mines >0	44,680	6.50	6.65	2.29
if mines = 0	894,440	7.94	7.51	4.91
Number of mines in mining districts				
all types	115,808	6.453	24.199	2
large	17,336	2.482	4.337	1
medium	27,522	2.163	2.512	1
small	78,914	6.892	22.268	2
producers	49,148	4.228	8.444	2
past producers	49,874	6.566	29.545	2
prospects	99,308	3.458	6.166	1
government mines	18,348	1.819	1.878	1

Source: Authors' computation from MRDS and DMPS-OLS datasets

[7] These mineral resources were chosen due to their quality of data in the MRDS and their economic significance in making machines, electrical components and a large portion of the other goods produced in the world.

2.3.3 Measuring Growth at the Sub-National Level Using Luminosity Data

To proxy for GDP growth, I use the Defense Meteorological Satellite Program's (DMPS) Operational Linescan System (OLS), which was primarily used to detect cloud cover but also captures light emitted from human activity proceeding sunsets. The growth in light emission for an area has been shown to correlate strongly with the growth in GDP for the area (Henderson et al., 2012). This data is available yearly from 1992 to 2013. The cell sizes are 30 arc seconds or roughly 1 kilometer by 1 kilometer. Each cell contains a value between 0 and 63 with 0 representing zero light emission and 63 representing the brightest that the satellite can measure. Areas that emit a large amount of light, such as cities, have the potential to hit the top-coded value.[8] This would lead to an underestimated growth value for these areas. A series of satellites were deployed for the 22-year period to make sure quality of the images were preserved. However, each new satellite that replaced the older version may have a slightly different calibration on recording night lights. Since most satellites overlap with each other over time, I create growth rates of night lights only within each satellite in order to maintain the same calibration of values while still obtaining a growth rate in each year. Descriptive statistics for district level luminosity and mining activity can be found in Table 2.1.

2.3.4 Institutional Data

To see how districts may be affected by the institutions of the country, I use two data sources. The first is the International Country Risk Guide (ICRG) from the Political Risk Services (PRS) group. This includes 11 variables such as corruption, internal conflict, military in politics, law and order and bureaucracy quality at an annual rate between 1984 to 2007 for 145 countries. The second data source is the Worldwide Governance Indicators (WGI), which contains data from 1996 to 2014 for over 200 countries and territories. This dataset creates 6 variables derived from 31 data sources that use surveys and expert assessments to gather a perception of the country's governance capabilities. These variables include voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. The prevalence of resources in a country or state could have major influences on the quality of institutions (Ross 2001) or conflict within a country (Berman et al. 2017). Additionally, increases in the development of a country can affect institutions leading to potential endogeneity issues.[9]

---

[8] Although the 'intensive' growth of the city will be muted, the extensive margin can still be measured. Additionally, I provide a robustness check whereby I exclude districts who have a large proportion of their cells to be top-coded and find no significant impact to the overall results.

[9] In order to account for this, I use initial values of institutional characteristics.

2.4 Empirical Analysis

I first discuss the identification strategy and describe the baseline analysis of the effects of resource-abundance on economic growth using exogenous price changes. Second, I analyze the role that institutions play in the development of resource-heavy areas. Third, I provide ways to measure the spillover effects of resource-rich areas and analyze the interaction that these areas have with capital cities and large populated areas. Fourth, I present an approach to analyze the effects of institutions and conflict on the behavior of spillovers within states with mining activity. Lastly, I discuss identification issues that arise from this method of analysis.

2.4.1 Baseline Specification

The first specification will aggregate all nine resources into one variable, abstracting from differences in the types of resources. As in Berman et al. (2017), I take the price of the commodity that is most abundant in the specific area.[10] Therefore let,

$$y_{i,c,t} = \beta_1(P_t * M_i^{tot}) + \mathbf{FE_i} + \mathbf{FE_{ct}} + \epsilon_{i,t} \tag{2.1}$$

where $y_{i,t}$ is log sum of light in district i at time t, P_t is the price of the most prevalent commodity, M_i^{tot} is the number of resource producers contained within the district and $P_t * M_i^{tot}$ is the interaction effect between resource abundance and prices. $\mathbf{FE_{ct}}$ is a vector of country and year interaction dummies along with their coefficients to control for country-time fixed effects, $\mathbf{FE_i}$ is the unobserved heterogeneity and $\epsilon_{i,c,t}$ is the error term. I do not include P_t or M^{tot} in equation 2.1 since these will be absorbed by the country-year fixed effects $\mathbf{FE_{ct}}$ and district fixed effects $\mathbf{FE_i}$ respectively. Applying first differences gives

$$y_{i,c,t} - y_{i,t-1} \equiv \Delta y_{it} = \beta_1(\Delta P_t * M_i^{tot}) + \mathbf{FE_i} + \mathbf{FE_{ct}} + \Delta\epsilon_{i,t}. \tag{2.2}$$

I then include further price lags to equation 2 such that

$$\Delta y_{it} = \sum_{l=0}^{T} \beta_l(\Delta P_{t-l} * M_i^{tot}) + \mathbf{FE_i} + \mathbf{FE_{ct}} + \Delta\epsilon_{i,t}. \tag{2.3}$$

To determine the amount of lags to keep in the specification, I assess where the statistical significance

[10] As a robustness, I also measure a weighted average price of all the resource commodities found in a particular district.

falls off and I also use the Akaike information criterion (AIC) and Schwartz/Bayesian information criterion (SBIC). Additionally, $(\Delta P_t * M_i^{tot})$ can be split by production sizes of mines, such as small, medium or large and also by ownership i.e. whether government or privately owned.[11] Mines that have become exhausted can also be added to the analysis to measure the impact that depleted resources have on resource-dependent districts.[12]

An issue arises when adding in country-year fixed effects with the explanatory variables. This leads to a high-dimensional matrix that needs to be inverted, which can be computationally difficult. As a solution, I implement the algorithm of Guimaraes and Portugal (2010) that converges to the solution instead of inverting a large matrix full of dummy variables. This method also allows me to control for district fixed effects that may influence the growth rate of development.

2.4.2 Multiple Resource Specification

Disaggregating mineral types gives the benefit of knowing what resources have a greater effect on local development than others, if any at all. This also alleviates any possible measurement error due to the construction of the aggregate price created in section 4.1. Given the 9 mineral products denoted as $s \in S$, I can rewrite equation 2 to be

$$\Delta y_{i,t} = \sum_{s=1}^{S} \beta_1^s (\Delta P_t^s * M_i^s) + \mathbf{FE_i} + \mathbf{FE_{st}} + \Delta \epsilon_{i,t} \tag{2.4}$$

2.4.3 Institutional Effects

Institutions of a country may play an important role in determining the allocation of mineral wealth. For instance, low rule of law and property rights or low regulatory quality may increase chances of hampering or aiding development of the mining region compared to the rest of the country.

[11] I also include in the main regression analysis district-level fixed effects in order to control for district specific unobserved heterogeneity that could affect the growth of districts.

[12] Furthermore, the growth of previous years may be strongly correlated with the growth in the current year. Therefore, I add to equation 2.4 lagged light growth such that

$$\Delta y_{i,t} = \beta_1 \Delta y_{i,t-1} + \sum_{l=1}^{T} \beta_l (\Delta P_{t-l} * M_i) + \mathbf{FE_i} + \mathbf{FE_{ct}} + \Delta \epsilon_{i,t}$$

This leads to endogeneity problems since $\epsilon_{i,t-1}$ shows in both $y_{i,t}$ and $y_{i,t-1}$ so that $E[\Delta y_{i,t-1}, \Delta \epsilon_{i,t}] \neq 0$. To account for this, I follow the suggestions of Arellano and Bond (1991) and use $y_{it-2}, y_{it-3}, \ldots$ as instruments.

Therefore using equation 2.4 and adding in institutional interactions we have

$$\Delta y_{i,t} = \sum_{s=1}^{S} \beta_1^s(\Delta P_t^s * M_i^s * Corr_i) + \sum_{s=1}^{S} \beta_1^s(\Delta P_t^s * M_i^s * Rul_i) + \sum_{s=1}^{S} \beta_1^s(\Delta P_t^s * M_i^s * BurQual_i) + \mathbf{FE_i} + \mathbf{FE_{ct}} + \Delta\epsilon_{i,t} \quad (2.5)$$

Although bureaucratic quality, rule of law and level of corruption are the three main institutional characteristics I focus on, I also consider military in politics, democratic accountability, government stability and socioeconomic conditions.

2.4.4 Spillover Effects

To analyze potential spillover effects, I use two main methods. The first and most straightforward method as done in Berman et al. (2017) is to classify districts that are adjacent to districts that have mines. This has the benefit of providing a concise measurement for spillovers; however, it does not take into account potential spillovers from other mining districts in the state. The second method looks at spillovers at a state level. This is done by summing all the mines within the state and interacting it with the price of the resources most prevalently found among them. This will show, on average whether a district (regardless of whether mines were located within its boundaries) benefited more or less from the fact that the state itself had mining activity. Each of these methods have benefits in describing the spillover effects of mining activity but take polar opposite views on the importance of distance from the resource areas themselves.[13] Applying both methods will provide a more detailed picture on how resource endowment effects interact with the state level economy.

[13] A third method adds the number of resource areas together but discounts the resource area with respect to the distance between the district of interest and the resource location such that

$$ResourceAccess_i = \sum_{j \in S} \frac{Res_j}{Dist_{ij}}.$$

However, since there are nearly 47,000 district within my sample, this method would be computationally intensive for little benefit. In the appendix C.2, I provide an example using Canada to compare the resource access spillover method with the statewide spillover method.

2.4.5 Benefits to Capitals Versus Mining Areas

An interesting further question is whether large cities and state capitals end up receiving a larger proportion of the gains from resources than the actual surrounding area where the resources are located. This is a concern to both local populations and national governments since many companies who have bought the mineral rights and are in the business of extracting these resources are concentrated in the major cities. Moreover, it may be the case that workers hired to extract resources in the region are brought in from more populated areas and bring little additional development to the surrounding area. Similarly, if the state or country has a highly concentrated form of government, one would expect a larger proportion of income to be siphoned to the administrative capitals.

To look at the spatial distributional effects of resource wealth on state capitals and resource abundant districts, I create an interaction term for each district for whether that district is a state capital ($Cap1$), how much that state is abundant in resources when excluding their own resources ($SRes$) and the prices of those resources (P). Therefore

$$\Delta Y_{ist} = \beta_1 Cap1_{is} \times SRes_s \times \Delta P_t + \beta_2 Cap1_{is} \times \Delta P_t + \beta_3 SRes_s \times \Delta P_t + \tag{2.6}$$

$$\beta_4 Res_{is} \times \Delta P_t + \mathbf{FE_i} + \mathbf{FE_{st}} + \Delta\epsilon_{ist}.$$

Where $Cap1_{is} \times SRes_s \times P_t$ is the 3-way interaction between a dummy for whether the district is a state capital, the amount of resources in the state, and the change in prices of the most prevalent commodity within the state. β_1 can then be interpreted as the added spillover effect that capitals receive over non-capital districts. I also include all relevant combinations of the interaction effect that would not be absorbed by the state-year fixed effects. β_2 is the effect on capitals from changes in commodity prices. For instance, if we believe that higher resource commodity prices increase the cost of construction and the cost of inputs in industries located within the state capital, we would expect that β_2 would be negative. β_3 is the coefficient measuring the effect any district gets from the combined amount of resources in the state as prices for those resources change, which one can think of as a type of spillover effect. β_4 is the effect of resources due to price changes in the district that produce resources. Next, I add in interaction effects of countrywide capitals and large cities to equation 2.6 such that

$$\Delta Y_{ist} = \beta_1 Cap0_{is} \times SRes_s \times \Delta P_t + \beta_2 Cap0_{is} \times \Delta P_t + \beta_3 SRes_s \times \Delta P_t + \tag{2.7}$$

$$\beta_4 Res_{is} \times \Delta P_t + \beta_5 Cap1_{is} \times SRes_s \times \Delta P_t + \beta_6 Cap1_{is} \times \Delta P_t +$$

$$\beta_7 SRes_s \times \Delta P_t + \beta_8 Res_{is} \times \Delta P_t +$$

$$\beta_9 City_{is} \times SRes_s \times \Delta P_t + \beta_{10} City_{is} \times \Delta P_t + \beta_{11} SRes_s \times \Delta P_t +$$

$$\beta_{12} Res_{is} \times \Delta P_t + \mathbf{FE_i} + \mathbf{FE_{ct}} + \Delta \epsilon_{ist}.$$

2.4.6 Institutional Effects on Spillovers

So far, this paper has provided a way to analyze institutional effects on mining locations in their own districts. However, it does not address how one could analyze the institutional effects on the flow of mining activity throughout the states? Adding a fourth interaction term to equation 2.7 would substantially complicate the interpretation of our results. I instead provide a simple method to analyze the effects of institutions on economic spillovers from mining activity. I first cluster countries together into four groups by their institutional characteristics by using k-mean clustering using Euclidean distances (Sumner and Vazquez (2014)). I cluster over three institutional variables that could directly affect the economic impact of mining activity. Bureaucratic quality was chosen to capture the ease of obtaining permits to increase mining activity when prices change. To account for property rights of minerals and the mines themselves, I include an institutional measure for rule of law. Finally, I include corruption due to the higher likelihood of mining revenue being siphoned to alternative areas. I use 1992 values in order to mitigate the effects that mining activity can have on institutions. I perform the k-mean clustering for several iterations, each time randomly choosing initial starting points to ensure there are consistent groupings.

The k-means clustering provides four distinct groups. The first group can be characterized by having average bureaucratic quality and corruption but low law and order (.73 standard deviations below the mean). Group 2 clusters around OECD countries with high-quality institutional variables, all being more than one standard deviation above the mean. Similarly, Group 3 can be classified as the weak institutions' group with all 3 measurements being lower than 1.07 standard deviations from the mean. Group 4 is the inverse of group 1 with high rule of law but low bureaucratic quality and corruption. For each group, I estimate equation 2.7 separately to analyze the behavior of spillovers due to different institutional regimes.

I also perform the same analysis but looking at the effect that conflict has on the distributional flow of mining activity. The variables of internal conflict, ethnic tension and external conflict were chosen to assist in grouping countries by different conflict environments. I again perform the k-mean clustering to find four distinct groups. Group 1 represents the highest stability of the groups, both internally and externally with all values being more than .4 standard deviations above the mean. Group 2 has the most conflict with all values being .98 standard deviations below the mean or lower. Group 3 is the external conflict group that has relatively stable internal characteristics while group 4 is the opposite with .98 and .81 standard deviations below the mean for internal conflict and ethnic tension respectively.

2.4.7 Identifying the Spatial Effects of Mines

A number of different identification issues arise when using mining location data and night-time luminosity satellite data to determine growth from resource abundance and I discuss how to address them below.

Direct Light Emissions from Mines

The first issue is that mining locations emit large amounts of light. Therefore, increased mining activity will increase the total light in a district regardless of how mining activity affects the overall local economy. To account for this, I use the spatial location of the mineral resources and create buffer regions around each one. I then erase the light data that are contained within the buffered region, leaving presumably all other economic activity in the region. I use various buffer distances for robustness: 4km, 6km and 10km. This does create possibilities where these buffer areas erase light data other than mining activity such as towns and cities. There is also still an issue that not all mines or resource areas are documented in the area. If these are randomly distributed, the estimates would not be biased. However, if these unobserved mines are strongly correlated to past and existing mines, then the effect of resource abundance will be biased upwards since these unobserved mines will not be erased from the light data.

Effect of Countries on World Prices

A key assumption in identifying the effects of mining activity on economic growth is that no one district or cluster of districts can affect global prices due to their increased economic growth. For robustness, I exclude countries that have a large share of global output and who experienced large growth over 1992 and 2013. The countries excluded are the United States and China in the narrowest set and India, China, Russia, Brazil, the United States and the European Union for the broadest set.

Mines Turnover

Another potential concern could be that mines shut down and new ones emerge within the time period of study. Accounting for this, I split the time periods into three groups. For 1992 to 1998, I use past producers as the active mines. For 1999 to 2006, I use current producers and for 2006 to 2013, I use occurrences and prospects. I also run the model specifications using all three groups for the entire sample.

Endogenous Institutions and Conflict

There is a possibility that increased mining revenues can affect the quality of certain country-level institutions. Particularly for conflict within a country, a large body of literature indicates that mining activity can increase the likelihood of conflict over time. Bazzi and Blattman (2014) provide a survey that illustrates the various channels in which resources can increase conflict within a country. In order to control for this relationship, I use initial values for the institutional variables. This also has the added benefit of mitigating the possibility that growth in development may affect institutions as well, leading to reverse causality issues.

Spatial and Temporal Correlation

Since both economic activity and mining tend to cluster spatially, I correct the standard errors using a spatial heteroskedasticity and autocorrelation consistent (HAC) correction which allows for both cross-sectional spatial correlation and location-specific serial correlation. This approach is similar to Berman et al. (2017), who look at the spatial effects of mining activity on conflict within Africa.[14] I assume that the temporal decay for the Newey-West/Bartlett kernel to be 5 years and a radius of 1000km for the spatial kernel.

---

[14]For reference to the HAC correct method applied, see Conley(1999) and Hsiang, Meng and Cane(2011).

2.5 Results

In this section, I first estimate the local effects that exogenous world prices have on mining districts. Next, I show the distributional effects of mining locations on the overall state and determine the role of institutions. In section 6, I analyze in more depth the revenue sharing policies of three countries and estimate their effects on development due to mining and world price increases.[15]

2.5.1 Local Effect of Mining Activity

Following the same structure as section 4, I begin with showing the results when aggregating all mineral products together and using the price of the most prevalent mining activity within the district. Regressing an interaction between the log difference in prices and a mining indicator on the log difference in total light growth, as in Columns 1 through 3 in Table 2.2 shows a clear negative relationship when looking at the immediate response to price increases. A one standard deviation increase of prices leads to 1.6 percentage points less growth in light compared to non-mining districts. This amounts to an estimated .96 percentage points slower growth rate for mining locations.[16] I discuss four explanations for this result, which turns out to be consistent through many specifications. First, increased development as measured by increased luminosity of a district may lag behind any increased revenue created by immediate price increases. Second, as described by Topp et al. (2008), capital investment and then subsequent increases in production have historically lagged behind surges in prices. Downes et. al. (2014) and Gruen and Kennedy (2006) find that lagged responses were greater before the 1970's amounting to a 2-year overall lag but have, in more recent times, reduced this lagged response. The third explanation could be due to the immediate effects of increased mining activity being concentrated in the areas that are being censored.[17] Lastly, the higher prices in relevant resources that the district produces may funnel funds into increasing the production capacity of the mining areas themselves instead of investing in projects that would emit light immediately or outside of mining areas. Columns 2 and 3 provide lagged responses of price increases on mining locations and see positive and significant effect on light growth for up to 5 years. Looking more specifically at those mines that are owned by a government entity, we see larger immediate negative coefficient from price increases and statistically insignificant effects on growth from lagged price increases on government mines.

[15]A majority of the results for this section can be found in the corresponding appendix.

[16] Henderson et al. (2012) estimate the elasticity of light with respect to GPD to be .6.

[17]As a robustness I redo the analysis without censoring the luminosity data and find negative, yet insignificant coefficients.

Table 2.2: Effect of commodity price and resource abundance on light growth

	(1)	(2)	(3)
district mine > 0			
x log diff in price	-0.111***	-0.107***	-0.131***
	(-6.84)	(-6.63)	(-8.29)
x lag(1) log diff in price		0.147***	0.293***
		(9.26)	(18.44)
x lag(2) log diff in price			0.205***
			(12.86)
x lag(3) log diff in price			0.0188
			(1.18)
x lag(4) log diff in price			0.0340**
			(2.03)
x lag(5) log diff in price			0.343***
			(19.25)
District fixed effects	Yes	Yes	Yes
Country year fixed effects	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes
N	939120	939120	751296

The dependent variable is growth in log sum of light from 1992 to 2013 with mine being a dummy variable that takes a value of one if a mine is located in the district . t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. For interpretation of coefficients, one standard deviation of log differences in price is 0.13 with the elasticity of light with respect to income being .6. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Appendix Table B.1 analyzes the local economic impact of mines based on a broad classification of production sizes. This immediate negative effect to growth due to price increases can be seen to be driven primarily from small mining operations, by far the most prevalent type of activity in the sample. The immediate impact of large mines is positive yet insignificant. This may be due to larger mines being more responsive to price increases or that some of the mining activity is not censored due to the size of the enterprise. Columns 2 through 4 show that the lagged effect of prices follows the same results as the combined mines case with large increases in nighttime luminosity from lagged prices.

Next, I break down the estimation by resource type using prices for each resource instead of using the price of the most prevalent resource. I find that different resource types have varying effects on the development of mining districts. Appendix Table B.2 shows the price effect of various resource-abundant areas that include iron, copper and tin. Appendix Table B.3 breaks resources down into aluminum, coal and zinc while Appendix Table B.4 shows the results for gold, silver, and nickel. As in the aggregate case, mining districts see a negative effect from initial price increases. While most resource locations see positive effects in subsequent periods, copper, zinc and silver show evidence of more persistent negative effects.

For the initial analysis of the effects of institutions on mining and economic activity, Appendix Table B.5 reports the estimated coefficients specified by equation 2.5. Not surprisingly, lower corruption and rule of law both mitigate the immediate slower growth that mining locations witness and provide higher growth in subsequent periods from an initial price increase. Furthermore, column 4 shows that higher external conflict increases the immediacy that mining districts respond to positive prices. This could be due to countries who are involved in more external conflicts perceiving mining locations as strategically as well as economically important. Additionally, higher bureaucratic quality shows negative coefficients for both the immediate effect and for subsequent periods due to world price increases. One explanation may be due to the effectiveness of the country to impose additional regulations or taxes on mining locations reducing the effectiveness of mining locations.

2.5.2 Distributional Effects of Mining Activity

Looking at spillover effects, Appendix Table B.6 shows that districts who were adjacent to mining areas see a statistically significant decrease initially but an increase one year after a price increase of the major commodity in the area. This effect is similar to the one found for the mining districts themselves, giving evidence that these adjacent districts are reliant on the mining activity around them. Columns 3 and 4 extend the analysis to estimating the effects that mines have on either a national/sub-national capital or a large city when a mine is present within their own district. We see that the effects of mining activity on these districts do not provide any significant effects.

In order to obtain a complete picture of the distributional effects of mining activity, Table 2.3 estimates the specification described in equation 2.7. I find that there is strong co-movement between large cities and mining districts within the state such that there is a delayed response from the initial price increase, where the city performs below average and then grows faster than the average large city in subsequent periods. This again suggests that large cities are tied to the mining activities within the state. In the full sample, I do not find evidence of national and sub-national capitals benefiting from increased mining revenue.

Table 2.3: Effect of commodity price and resource abundance on light growth: State wide spillover effects

	(1)	(2)	(3)	(4)
district mine > 0				
x log diff in price	-0.107***	-0.102***	-0.125***	-0.126***
	(-6.63)	(-5.87)	(-5.85)	(-5.87)
x lag(1) log diff in price	0.147***	0.151***	0.152***	0.131***
	(9.26)	(8.91)	(8.98)	(7.59)
# of state mines				
x log diff in price		-0.0000506	0.0000145	0.0000122
		(-0.87)	(0.24)	(0.20)
x lag(1) log diff in price		-0.0000352	-0.0000360	-0.000101*
		(-0.62)	(-0.63)	(-1.74)
x log diff in price x country capital			0.0233	0.0219
			(0.40)	(0.38)
x log diff in price x state capital			-0.0183	-0.0164
			(-1.15)	(-1.01)
x log diff in price x large city			-0.0323***	-0.0299***
			(-5.74)	(-5.23)
x lag(1) log diff in price x country capital				-0.0226
				(-0.42)
x lag(1) log diff in price x state capital				0.0190
				(1.26)
x lag(1) log diff in price x large city				0.0243***
				(4.60)
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	939120	938980	938980	938980

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

2.5.3 The Role of Institutions

Institutional characteristics such as corruption may affect a country's allocation of increased mining revenues. Table 2.4 provides estimates of statewide spillover effects on four different clusterings of countries based on their initial indicators of levels of bureaucratic quality, corruption and rule of law.[18] Cluster 1, represented by low law and order but average bureaucratic quality and corruption see moderate, yet still significant local effects on the mining districts. The strong institution group, cluster 2, also has lower local

[18]See Appendix Tables B.7 and B.8 for the descriptive statistics and country lists for each cluster.

effects of mining within their own district. However, districts that are within a state with prevalent mining activity receive a positive and statistically significant increase to their growth when strong institutions are present, regardless if they contain a large city. This may suggest that countries with strong bureaucratic quality, rule of law and low corruption are more likely to have systems or economies that disperse the benefits of mining activities. Cluster 3, which can be characterized as the weak institution cluster, loses the local effects of mining activity immediately with no statistically significant effect of any lagged prices interacted with mining activity. Furthermore, it is the only group that provides statistically significant evidence of the state capital benefiting from increased mining activity within the state. In order to interpret the significance of this coefficient, I calculate that a one standard deviation in increased prices results in a 4.1 percentage point increase in the growth in lights on average for districts that include the state capitals or a 2.46 percentage point increase in income. Cluster 4 which represents the high rule of law but low indexes on bureaucratic quality and corruption sees the highest magnitude for the local effects of mining activity. Unlike the overall estimation, countries that belong in cluster 4 see their cities who are in mining states grow more slowly than other districts. Comparing clusters 1, 2 and 4 together suggests that rule of law is the leading driver to higher impacts of increased mining activity locally.

2.5.4 The Role of Conflict

Different types of conflict may have varying effects on the distributional characteristics of mining activity. This is particularly true of external conflicts which early in the paper have shown to actually increase the developmental impact of mining locations. Table 2.5 shows the estimates of the specification described by equation 2.7 but grouped by four different conflict groups.[19] Starting with cluster 1, which is represented by countries with low levels of each type of conflict, we see that this group behaves almost identically to the high institutional quality group in the last section. Further similarities are not seen when observing the overall high conflict group, cluster 2, with the overall low institution group when looking at the local effects of commodity prices on the growth of mining locations. However, cluster 2 does see the state capitals receiving a persistent increase in growth when mining locations are prevalent, similar to that of the weak institution country group. Furthermore, cluster 2 does not see any increased growth in large cities that are not the state capital which is seen in other groups.

[19]See Appendix Tables B.9 and B.10 for the descriptive statistics and country lists for each cluster.

Table 2.4: Effect of commodity price and resource abundance on light growth: Institution groups

	(1)	(2)	(3)	(4)
district mine > 0				
x log diff in price	-0.0673***	-0.103***	-0.278**	-0.319***
	(-3.06)	(-2.74)	(-2.11)	(-3.61)
x lag(1) log diff in price	0.100***	0.143***	0.152	0.305***
	(5.43)	(4.96)	(1.36)	(3.79)
# of state mines				
x log diff in price	-0.0000418	0.000769	0.00412	-0.00155*
	(-1.02)	(1.30)	(1.26)	(-1.71)
x lag(1) log diff in price	-0.0000241	0.00157***	-0.00443	0.000505
	(-0.60)	(2.78)	(-1.37)	(0.60)
x log diff in price x country capital	-0.00299	0.0714	-0.0214	0.0184
	(-0.06)	(0.10)	(-0.03)	(0.07)
x lag(1) log diff in price x country capital	-0.0129	0.132	-0.0964	-0.0395
	(-0.26)	(0.16)	(-0.19)	(-0.23)
x log diff in price x state capital	0.00119	-0.0269	-0.0900	-0.00463
	(0.07)	(-1.04)	(-1.30)	(-0.07)
x lag(1) log diff in price x state capital	-0.00363	0.0261	0.111*	-0.0281
	(-0.25)	(1.07)	(1.77)	(-0.43)
x log diff in price x large city	-0.0232***	-0.0389***	-0.0403	0.0356
	(-4.57)	(-4.44)	(-0.77)	(0.81)
x lag(1) log diff in price x large city	0.0135***	0.0539***	0.0193	-0.0914**
	(2.93)	(6.49)	(0.45)	(-2.36)
Institution Cluster	Cluster 1	Cluster 2	Cluster 3	Cluster 4
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	222640	327140	125980	102600

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01. Cluster 1 is represented by low rule of law with average corruption and bureaucracy. Cluster 2 has strong institutions while cluster 3 has weak institutions. Cluster 4 is represented by high corruption, low bureaucracy but high rule of law.

Next, for cluster 3 that is represented by high external conflict and lower levels of ethnic tension and internal conflict, we see the exact same statistically significant effects found in the overall sample although with weaker magnitudes. Cluster 4, which is characterized by low external conflict but high internal conflict and ethnic tension, shows that districts that are within mining states actually receive a negative effect from increases in prices. In the initial period these districts show a positive growth compared to districts in other states when prices increase. However, in the subsequent periods these districts see a dampening of their growth due to the initial price increase. This could be due to internal conflicts rising up within those states for control of the overall mining activities.

2.6 Differences in Revenue Sharing Policies

Many countries have enacted revenue sharing arrangements to address a variety of different concerns. Bauer et. al. (2016) describe these as: the attempt to recognize local claims on resources, a measure to counteract any negative impacts that resource extraction may provide, promoting development in resource-abundant regions and reducing the likelihood of violent conflict. However, resource sharing policies vary widely between countries. In this section I look at three specific countries, Chile, Argentina and Brazil, who have largely different revenue sharing policies to evaluate their effectiveness using the methods in this paper.

Starting with the least involved in their revenue sharing arrangements, Chile does not treat revenue from mineral extraction differently from other non-resource revenues and does not add additional taxes to mining activities. Chile's form of government, unlike the federal form of Argentina and Brazil, is Unitary. This means all revenues get directed to a central entity and distributed through them. Argentina, on the other hand, has the largest royalties imposed on mining activities and, unlike Chile, are collected directly by the subnational instead of national government. Indeed, it has been codified in the Argentinian constitution that local populations have a right to a share of resource revenues. Brazil also enacts additional royalties and are collected by the national government. They then enact a 'derivation based' intergovernmental transfer program to redirect the funds back to the original or adjacent areas.

Table 2.6 compares these countries by estimating the model specification in equation 2.7 in order to see the local and spillover effects of mining locations. Column 1 shows the results when looking specifically at Chilean districts which shows that districts with mining activity see a positive increase in the year after the initial price increase. However, unlike the other countries in this comparison, and with the entire sample, the

Table 2.5: Effect of commodity price and resource abundance on light growth: Conflict groups

	(1)	(2)	(3)	(4)
district mine > 0				
x log diff in price	-0.0759*	-0.284***	-0.0547	-0.178***
	(-1.73)	(-2.84)	(-1.61)	(-3.99)
x lag(1) log diff in price	0.156***	0.266***	0.0873***	0.143***
	(4.52)	(3.17)	(3.01)	(3.98)
# of state mines				
x log diff in price	-0.000307	-0.00456***	-0.0000459	0.00171***
	(-0.55)	(-3.73)	(-0.78)	(3.30)
x lag(1) log diff in price	0.00125**	0.00244**	-0.00000387	-0.00157***
	(2.32)	(2.16)	(-0.07)	(-3.15)
x log diff in price x country capital	0.00306	0.0104	0.00211	-0.0581
	(0.04)	(0.02)	(0.01)	(-0.39)
x lag(1) log diff in price x country capital	0.0132	-0.00202	-0.0375	0.0261
	(0.16)	(-0.00)	(-0.24)	(0.20)
x log diff in price x state capital	-0.0207	-0.0428	-0.00964	-0.0253
	(-0.67)	(-0.60)	(-0.41)	(-0.78)
x lag(1) log diff in price x state capital	0.0269	0.171**	-0.00158	0.00392
	(0.93)	(2.49)	(-0.07)	(0.13)
x log diff in price x large city	-0.0352***	-0.0662	-0.0199**	-0.0288***
	(-3.27)	(-1.63)	(-2.37)	(-2.63)
x lag(1) log diff in price x large city	0.0327***	0.00240	0.0135*	0.0409***
	(3.22)	(0.06)	(1.83)	(3.99)
Conflict Cluster	Cluster 1	Cluster 2	Cluster 3	Cluster 4
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	270940	45600	200180	295680

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01. Cluster 1 is represented by low internal and external conflict. Cluster 2 has high internal and external conflict. Cluster 3 has low internal conflict and high external conflict and cluster 4 has high internal conflict and low external conflict.

Table 2.6: Effect of commodity price and resource abundance on light growth: Revenue sharing policy analysis

	(1)	(2)	(3)
district mine > 0			
x log diff in price	-0.249	-0.125*	-0.162***
	(-1.50)	(-1.73)	(-3.99)
x lag(1) log diff in price	0.231***	0.324	0.340***
	(4.88)	(1.21)	(10.27)
x lag(2) log diff in price	-0.0202	-0.147	0.0695*
	(-0.15)	(-1.18)	(1.77)
x lag(3) log diff in price	-0.131**	0.0111	0.110**
	(-2.23)	(0.14)	(2.35)
# of state mines			
x log diff in price	0.000519	0.00610	0.00168
	(0.37)	(0.87)	(0.25)
x lag(1) log diff in price	0.000106	-0.00959	-0.000975
	(0.07)	(-1.35)	(-0.15)
x log diff in price x state capital	-0.0269	-0.0244	0.00373
	(-0.68)	(-0.50)	(0.46)
x log diff in price x large city	-0.0371	-0.00404	-0.0116*
	(-0.84)	(-0.75)	(-1.68)
x lag(1) log diff in price x state capital	0.1230**	0.0559	0.00859
	(1.97)	(1.05)	(0.93)
x lag(1) log diff in price x large city	0.0170	0.100	0.0931**
	(0.45)	(1.29)	(2.03)
District fixed effects	Yes	Yes	Yes
Country year fixed effects	Yes	Yes	Yes
Country	Chile	Argentina	Brazil
N	918	9036	99072

The dependent variable is growth in log sum of light from 1992 to 2013 with mine being a dummy variable that takes a value of one if a mine is located in the district . t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. For interpretation of coefficients, one standard deviation of log differences in price is 0.13 with the elasticity of light with respect to income being .6. Significance levels are: * 0.10, ** 0.05, *** 0.01.

increased growth stops and reverses direction by the third year. In relation to this, we do see state capitals of these mining areas receiving positive and statistically significant growth compared to other districts in the country. Column 2 reports Argentina's results which shows there is no statistically significant result of the local effects of mining areas due to price changes. Column 3 shows that Brazilian mining districts see the largest growth over the longest time period. Furthermore, cities within resource-abundant states also see a statistically significant increase in their light growth due to increases in last year's world prices.

2.7 Conclusion

Although the resource curse has been studied thoroughly at an international level, local effects of resource activity are much less understood. This paper shows how the effects of mining activity can benefit or hinder certain locations in a country and can vary a great amount depending on certain country characteristics such as institutions, the degree of conflict and revenue sharing policies. Overall, I find that districts and cities within the same state as mining districts respond similarly to exogenous price shocks and that, over the long run, the region benefits from the increases in commodity prices. However, low quality institutions and internal strife can change the distributional impact of mining activities. Unfortunately, the availability for the night time luminosity data is only until 2013, coinciding with the downturn of commodities prices. Looking at other remote sensing data such as the Visible Infrared Imaging Radiometer Suite (VIIRS) which is monthly data, higher resolution and spanning from 2012 to 2018 would further increase our understandings of the boom and bust super cycle of resource commodities. Reducing the sample of countries to those that have district-level population data would further help quantify the effects mining activity has on development. This paper's findings are important for national and regional planners who need to determine the institutional environment in order to benefit from resources. Its findings also determine how the state, and more specifically which parts of the state, are dependent on mining activity.

APPENDIX A

APPENDIX FOR CHAPTER 1: WHY DON'T AFRICAN COUNTRIES TRADE MORE WITH EACH OTHER? THE ROLE OF BORDER CROSSINGS IN GENERAL EQUILIBRIUM

Section A.1 of this appendix includes additional tables and figures. Section A.2 presents model details. Section A.3 discusses technical aspects of the identification and calibration techniques.

A.1 Additional Tables and Figures

Table A.1: 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 A.2: Proportion of trade for 2008 and 2014 by sector

	2008				2014			
Sector Name	**Total Exports**	**Total Imports**	**African Imports**	**Non-Adjacent Imports**	**Total Exports**	**Total Imports**	**African Imports**	**Non-Adjacent Imports**
AnimalProd	0.01	0.01	0.02	0.01	0.01	0.02	0.03	0.02
Chemicals	0.03	0.09	0.09	0.09	0.04	0.09	0.11	0.10
FoodStuffs	0.03	0.03	0.06	0.05	0.04	0.04	0.08	0.05
Footwear	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00
Hides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery	0.04	0.24	0.12	0.14	0.04	0.21	0.13	0.16
Metals	0.11	0.07	0.14	0.14	0.10	0.07	0.09	0.15
MineralProd	0.46	0.19	0.27	0.36	0.37	0.19	0.22	0.28
Misc	0.01	0.04	0.02	0.02	0.01	0.04	0.02	0.02
Plastics	0.01	0.04	0.04	0.04	0.01	0.04	0.04	0.05
Stone/Glass	0.17	0.02	0.02	0.01	0.15	0.03	0.05	0.01
Textiles	0.01	0.03	0.03	0.02	0.01	0.04	0.03	0.01
Transport	0.04	0.12	0.08	0.07	0.04	0.10	0.08	0.07
VegProd	0.04	0.04	0.05	0.03	0.05	0.05	0.06	0.04
WoodProd	0.02	0.03	0.06	0.02	0.01	0.02	0.03	0.03
Other	0.01	0.04	0.00	0.00	0.12	0.04	0.00	0.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: UNCOMTRADE.dta

Table A.3: Dependent Variable: log difference in border wait time

	(1)
Average Time of Non Controlled Borders	-0.0195
	(-0.03)
N	268
R^2	0.294

The dependent variable is growth in aggregate 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 A.4: Growth of trade flows from infrastructure changes: Including rest of world trade

	(1)	(2)	(3)	(4)	(5)	(6)
Change in Border Wait Times (log)	-0.191**	-0.346***	-0.737***	-0.160*	-0.225**	-0.290**
	(-1.97)	(-3.44)	(-6.16)	(-1.86)	(-2.50)	(-2.38)
Change in Drive Times		0.00179***	0.00165***		0.000737***	0.000777***
		(12.49)	(10.78)		(5.06)	(5.15)
Change in Port Costs		4.605***	3.104***		-1.604*	-1.167
		(5.25)	(3.36)		(-1.72)	(-1.22)
AboveAvgDist Interaction			0.533***			0.00351
			(4.69)			(0.03)
Change in Tariffs			0.399***			0.449***
			(9.11)			(11.11)
Adjacency/Non Adjacency	Both	Both	Both	Non adjacent	Non adjacent	Non adjacent
N	4710	4035	4005	3855	3180	3165
R^2	0.209	0.254	0.275	0.257	0.288	0.321

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 A.5: Growth of trade flows from infrastructure changes 15 sector case: exogenous border instrument sectors 1-5

	(1)	(2)	(3)	(4)	(5)
Change in Border Wait Times (log)	-1.254*	-0.824	-0.938	-1.321	-0.679
	(-1.94)	(-1.01)	(-1.12)	(-1.53)	(-0.80)
Change in Drive Times	0.00203***	0.00252***	0.00128	0.00109	0.00110
	(2.89)	(2.85)	(1.41)	(1.16)	(1.20)
AboveAvgDist Interaction	0.854*	1.490**	3.292***	1.826***	1.940***
	(1.71)	(2.37)	(5.10)	(2.74)	(2.97)
Number of Documents	1.875**	1.888*	3.917***	0.124	0.365
	(2.16)	(1.72)	(3.48)	(0.11)	(0.32)
N	227	227	227	227	227
R^2	0.238	0.265	0.338	0.172	0.239

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. Column 1 Animal and Animal Product, Column 2 Vegetable Products, Column 3 Foodstuffs, Column 4 Mineral Products, Column 5 Chemicals and Allied Products.

Table A.6: Growth of trade flows from infrastructure changes 15 sector case: exogenous border instrument sectors 6-10

	(1)	(2)	(3)	(4)	(5)
Change in Border Wait Times (log)	-0.794*	-0.448	-0.777*	-0.952**	-0.545
	(-1.78)	(-1.30)	(-1.70)	(-2.08)	(-1.59)
Change in Drive Times	0.00206***	0.00102*	0.00211***	0.00237***	0.000792
	(2.65)	(1.70)	(2.66)	(2.97)	(1.33)
AboveAvgDist Interaction	0.874*	0.528	0.933**	0.588	0.298
	(1.92)	(1.51)	(2.00)	(1.26)	(0.85)
Number of Documents	1.081	-0.311	3.146***	2.575***	-0.355
	(1.16)	(-0.43)	(3.31)	(2.69)	(-0.50)
N	222	222	222	222	222
R^2	0.275	0.245	0.303	0.317	0.293

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. Column 1 Plastics and Rubber, Column 2 Raw Hides, Skins, Leather and Furs, Column 3 Wood and Wood Products, Column 4 Textiles, Column 5 Footwear and Headgear.

Table A.7: Growth of trade flows from infrastructure changes 15 sector case: exogenous border instrument sectors 11-15

	(1)	(2)	(3)	(4)	(5)
Change in Border Wait Times (log)	-0.920**	-0.797	-1.016**	-0.822*	-0.727*
	(-2.17)	(-1.59)	(-2.15)	(-1.80)	(-1.70)
Change in Drive Times	0.00154**	0.00225***	0.00128	0.00153*	0.00209***
	(2.10)	(2.59)	(1.56)	(1.92)	(2.82)
AboveAvgDist Interaction	0.548	0.450	0.773	0.506	0.579
	(1.27)	(0.88)	(1.60)	(1.08)	(1.33)
Number of Documents	1.762**	1.785*	2.321**	0.512	2.153**
	(1.99)	(1.71)	(2.35)	(0.54)	(2.42)
N	222	222	222	222	222
R^2	0.276	0.271	0.261	0.257	0.242

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. Column 1 Stone and Glass Column 2 Metals, Column 3 Machinery and Electrical, Column 4 Transportation, Column 5 Miscellaneous

Table A.8: Growth of trade flows from infrastructure changes 3 sector case: exogenous border instrument

	(1)	(2)	(3)
Change in Border Wait Times (log)	-1.231***	-0.812***	-0.792***
	(-4.29)	(-4.74)	(-3.82)
Change in Drive Times	0.00234***	0.00172***	0.00174***
	(4.70)	(5.77)	(4.84)
AboveAvgDist Interaction	1.224***	0.616***	0.667***
	(4.18)	(3.53)	(3.16)
Number of Documents	3.938***	1.983**	1.699*
	(3.96)	(2.22)	(1.85)
Sectors	Ag	Manf	Res
N	666	1554	1110
R^2	0.270	0.265	0.242

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 A.9: Growth of trade flows from infrastructure changes 15 sector case: exogenous border instrument, aggregated transportation costs

	(1)	(2)	(3)	(4)	(5)
Time Costs Change (Upper Bound)	-0.561***	-0.668***	-0.647***	-1.137*	-1.107**
	(-3.33)	(-3.84)	(-3.78)	(-1.95)	(-2.02)
AboveAvgDistInteraction		0.355**			-0.0411
		(2.46)			(-0.24)
AboveAveTimeInteraction			0.386***	-0.0291	
			(2.66)	(-0.16)	
IV Regress	No	No	No	Yes	Yes
N	3600	3600	3600	2355	2355
R^2	0.246	0.248	0.248	0.301	0.302

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 A.10: Growth of trade flows from infrastructure changes 15 sector case: exogenous border instrument, aggregated transportation costs

	(1)	(2)	(3)	(4)	(5)
Time Costs Change (Lower Bound)	-0.591***	-0.703***	-0.676***	-1.115*	-1.083**
	(-3.51)	(-4.04)	(-3.95)	(-1.95)	(-2.03)
AboveAvgDistInteraction		0.365**			-0.0468
		(2.53)			(-0.27)
AboveAvgTimeInteraction			0.389***	-0.0348	
			(2.68)	(-0.19)	
IV Regress	No	No	No	Yes	Yes
N	3600	3600	3600	2355	2355
R^2	0.246	0.248	0.248	0.303	0.303

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 A.11: 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 A.12: Growth of trade flows from infrastructure changes 15 sector case: exogenous border instrument, aggregated transportation costs

	(1)	(2)	(3)	(4)	(5)
Time Cost Change	-0.262*	-0.386**	-0.385**	-1.167**	-1.160**
	(-1.78)	(-2.40)	(-2.45)	(-1.97)	(-2.04)
AboveAvgDistInteraction		0.258*			-0.0242
		(1.91)			(-0.15)
AboveAvgTimeInteraction			0.302**	-0.0250	
			(2.22)	(-0.15)	
IV Regress	No	No	No	Yes	Yes
N	5038	5038	5038	2689	2689
R^2	0.206	0.207	0.207	0.300	0.301

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 A.13: Growth of trade flows from infrastructure changes: Constant Routes

	(1)	(2)	(3)	(4)	(5)	(6)
Change in Border Wait Times (log)	-0.0866	-0.205	-0.343*	-0.0447	-0.0342	-0.0773
	(-0.47)	(-1.09)	(-1.84)	(-0.24)	(-0.17)	(-0.39)
Change in Drive Times		0.00219***	0.00199***		0.000152	0.000236
		(10.76)	(8.98)		(0.57)	(0.85)
AboveAvgDist Interaction			0.282***			-0.0284
			(2.58)			(-0.28)
Change in Tariffs			0.448***			0.527***
			(8.53)			(10.67)
Number of Documents			-0.365			-0.370
			(-1.10)			(-1.20)
Adjacency/Non Adjacency	Both	Both	Both	Non adjacent	Non adjacent	Non adjacent
N	3405	3330	3330	2520	2490	2490
R^2	0.213	0.245	0.265	0.276	0.276	0.314

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 A.14: Growth of trade flows from infrastructure changes 15 sector case: exogenous border instrument, aggregated transportation costs with constant routes

	(1)	(2)	(3)	(4)	(5)
Time Cost Change	-0.984***	-3.428***	0.402	-81.68	-127.9
	(-6.46)	(-4.82)	(1.19)	(-1.40)	(-1.36)
AboveAvgDistInteraction		2.510***			124.8
		(3.52)			(1.35)
AboveAvgTimeInteraction			-1.586***	79.54	
			(-4.60)	(1.39)	
IV Regress	No	No	No	Yes	Yes
N	5113	5113	5113	2689	2689
R^2	0.211	0.213	0.215	0.292	0.258

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 A.15: Growth of trade flows from infrastructure changes: Symmetric Border crossings

	(1)	(2)	(3)	(4)	(5)	(6)
Change in Border Wait Times (log)	-0.342***	-0.562***	-1.075***	-0.279***	-0.402***	-0.752***
	(-3.14)	(-4.80)	(-7.54)	(-2.81)	(-3.53)	(-4.70)
Change in Drive Times		0.00216***	0.00178***		0.000582**	0.000503*
		(10.00)	(8.01)		(2.02)	(1.79)
Change in Port Costs		5.495***	4.431***		-0.662	-0.576
		(4.60)	(3.68)		(-0.47)	(-0.41)
AboveAvgDist Interaction			0.783***			0.439***
			(5.87)			(3.10)
Change in Tariffs			0.462***			0.519***
			(8.92)			(10.54)
Adjacency/Non Adjacency	Both	Both	Non adjacent	Non adjacent	Non adjacent	Adjacent only
N	4230	3330	3330	3390	2490	2490
R^2	0.215	0.258	0.286	0.261	0.280	0.322

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 A.16: Growth of trade flows from infrastructure changes: Imports with no supplementation

	(1)	(2)	(3)	(4)	(5)	(6)
Change in Border Wait Times (log)	0.146	-0.0180	-0.172	0.152	-0.0408	-0.296**
	(1.47)	(-0.18)	(-1.39)	(1.60)	(-0.45)	(-2.29)
Change in Drive Times		0.00125***	0.000840***		0.00157***	0.00124***
		(6.88)	(3.90)		(6.83)	(4.58)
Change in Port Costs		7.424***	6.840***		4.499***	4.097***
		(6.67)	(6.01)		(3.41)	(3.06)
AboveAvgDist Interaction			0.329***			0.410***
			(2.59)			(3.11)
Change in Tariffs			-0.185***			0.0353
			(-3.70)			(0.73)
Adjacency/Non Adjacency	Both	Both	Both	Non adjacent	Non adjacent	Non adjacent
N	4410	3360	3330	3555	2505	2490
R^2	0.423	0.384	0.384	0.457	0.366	0.370

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 A.17: Growth of trade flows from infrastructure changes: Exports with no supplementation

	(1)	(2)	(3)	(4)	(5)	(6)
Change in Border Wait Times (log)	-0.625***	-0.777***	-0.950***	-0.179**	-0.163**	-0.0414
	(-6.59)	(-7.90)	(-7.78)	(-2.23)	(-2.06)	(-0.37)
Change in Drive Times		0.000941***	0.00116***		-0.000324	-0.0000297
		(5.27)	(5.47)		(-1.60)	(-0.13)
Change in Port Costs		9.600***	8.934***		0.863	1.516
		(8.78)	(7.99)		(0.74)	(1.29)
AboveAvgDist Interaction			0.176			-0.245**
			(1.41)			(-2.11)
Change in Tariffs			0.117**			0.212***
			(2.39)			(5.00)
Adjacency/Non Adjacency	Both	Both	Both	Non adjacent	Non adjacent	Non adjacent
N	4410	3360	3330	3555	2505	2490
R^2	0.448	0.489	0.493	0.492	0.538	0.545

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 A.18: Growth of trade flows from infrastructure changes: PPML estimation with imports and export with no supplementing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Border Wait Time (log)	-0.221***	-0.121***	-0.142***	-0.232***	-0.174***	-0.0957***	-0.127***	-0.183***
	(-16.26)	(-8.96)	(-10.49)	(-16.62)	(-17.25)	(-10.14)	(-13.59)	(-15.97)
Tariffs (log)	-0.257***	-0.137***	-0.150***	-0.262***	-0.120***	-0.00671	-0.0549***	-0.122***
	(-22.88)	(-11.23)	(-11.92)	(-23.01)	(-14.14)	(-0.74)	(-6.38)	(-13.28)
Border-Road Time Interaction		-0.166***				-0.177***		
		(-20.48)				(-27.26)		
Border-Distance Interaction			-0.154***				-0.163***	
			(-17.71)				(-25.92)	
Port Costs (log)				-0.00164				-0.185
				(-0.01)				(-1.27)
Trade Flow	Import	Import	Import	Import	Exports	Exports	Exports	Exports
N	6648	6648	6648	5878	7465	7465	7465	6570
R^2	0.753	0.772	0.767	0.748	0.695	0.732	0.726	0.693

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 A.19: Growth of trade flows from infrastructure changes 15 sectors case with 3 year averages

	(1)	(2)	(3)	(4)	(5)	(6)
Change in Travel Costs	-0.537***	-1.357***	-0.118	-0.110	-1.056	0.124
	(-2.90)	(-4.62)	(-0.64)	(-0.25)	(-0.28)	(0.28)
Change in Tariffs				0.443***	0.654***	0.419***
				(18.35)	(7.33)	(17.24)
Adjacency/Non Adjacency	Both	Both	Non adjacen	Both	Both	Non adjacent
Rest of World	Yes	No	Yes	Yes	No	Yes
N	6540	3765	5505	6313	3550	2335
R^2	0.163	0.210	0.194	0.759	0.920	0.745

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 A.20: Growth of trade flows from infrastructure changes 15 sectors case with institution interactions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Change in Travel Costs	-0.687***	-0.500	-0.663***	-0.479	-0.649***	-0.495	-0.627***	-0.453
	(-4.90)	(-1.58)	(-4.75)	(-1.54)	(-4.67)	(-1.60)	(-4.44)	(-1.48)
Change in Tariffs	0.400***	0.379***	0.400***	0.379***	0.399***	0.379***	0.400***	0.379***
	(30.14)	(22.64)	(30.13)	(22.64)	(30.05)	(22.63)	(30.16)	(22.70)
Regulatory Qual. Int.	-0.334**	-0.136						
	(-1.98)	(-0.69)						
Rule of Law Int.			-0.146	-0.0970				
			(-1.10)	(-0.63)				
Political Corruption Int.					-0.302**	-0.194		
					(-2.08)	(-1.16)		
Political Stability Int.							-0.161	-0.290*
							(-1.01)	(-1.71)
FE	No	Yes	No	Yes	No	Yes	No	Yes
N	1493	1493	1493	1493	1493	1493	1493	1493
R^2	0.393	0.670	0.392	0.670	0.393	0.670	0.392	0.670

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 A.21: GE multiple sector results

Type	α	β	θ^s	μ^s	StdEr	R^2
Own Calibration Ag	-23	-1.4	-7.3449	-0.1402	0.0417	0.0476
Own Calibration Manf	-23	-1.4	-3.9976	-0.2667	0.0449	0.1768
Own Calibration Res	-23	-1.4	6.8117	-0.1105	0.0288	0.0366
Own Calibration Ag	-30.2	-27.9	-1.1590	-4.1426	2.5541	0.0165
Own Calibration Manf	-30.2	-27.9	-1.1919	-5.8859	2.4824	0.0076
Own Calibration Res	-30.2	-27.9	2.0076	-0.2684	2.2579	.0464
EK Ag	-3.85	-3.04	-1.808	-2.8593	0.9756	0.0359
EK Manf	-3.85	-3.04	-1.0059	-5.2331	0.6652	0.0017
EK Res	-3.85	-3.04	0.5430	-1.2440	1.7650	0.0045
AL Ag	-0.67	-0.33	2.7966	-2.5527	2.1621	0.0024
AL Manf	-0.67	-0.33	0.023	-4.7521	2.3939	0.0012
AL Res	-0.67	-0.33	0.0221	-0.1033	1.6385	0.0031

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 A.22: Percentage point change in trade patterns with no improvements. Universal gravity model approach

Country	Agriculture	Manufacturing	Resources
Angola	-22.00	-13.75	-14.80
Botswana	-22.39	-28.93	-36.74
Burundi	-34.82	-28.92	-31.80
Congo; Dem. Rep.	-33.40	-32.42	-34.88
Kenya	-17.05	-11.88	-8.40
Lesotho	-3.76	-23.56	-16.15
Malawi	-22.49	-15.00	-13.37
Mozambique	-33.03	-38.21	-37.10
Namibia	6.53	5.36	2.20
Rwanda	-5.81	-10.65	-10.68
South Africa	-7.60	-11.60	-0.97
Swaziland	-11.68	-12.88	-16.13
Tanzania	-12.86	-1.86	-7.94
Uganda	-4.66	-7.64	-13.98
Zambia	-6.52	0.96	-11.83
Zimbabwe	-0.88	6.95	-4.17
Weighted Avg	-12.85	-12.10	-8.67

Table A.23: Percentage point change in trade patterns with 3 hour borders. Universal gravity model approach

Country	Agriculture	Manufacturing	Resources
Angola	16.53	6.40	12.94
Botswana	6.24	1.915	3.87
Burundi	7.09	2.99	8.50
Congo; Dem. Rep.	18.75	8.58	20.10
Kenya	16.36	9.19	12.32
Lesotho	2.34	0.397	2.42
Malawi	8.48	1.38	6.27
Mozambique	11.28	3.72	7.03
Namibia	8.28	3.39	10.22
Rwanda	6.11	3.38	5.73
South Africa	12.12	4.36	13.44
Swaziland	10.63	0.84	2.58
Tanzania	12.91	5.94	10.56
Uganda	14.68	7.22	9.81
Zambia	15.62	5.27	12.24
Zimbabwe	10.88	4.17	9.40
Mean	11.14	4.322	9.21

Table A.24: Percentage point change in trade patterns with 3 hour borders: for internal and foreign trade. Universal gravity model approach

Country	Inter-trade Agriculture	Inter-trade Manufacturing	Inter-trade Resources	Foreign trade Agriculture	Foreign trade Manufacturing	Foreign trade Resources
Angola	21.03	57.83	13.61	0.17	-1.93	-1.33
Botswana	8.23	25.69	6.95	-0.12	-3.22	-1.11
Burundi	9.61	22.02	11.13	1.297	5.76	-0.97
Congo; Dem. Rep.	27.63	79.34	29.35	0.59	1.32	-0.99
Kenya	19.97	69.55	13.45	-0.28	-3.37	-0.94
Lesotho	2.95	13.00	3.073	-0.51	-8.36	-1.296
Malawi	10.38	10.48	6.718	0.59	2.01	-0.797
Mozambique	16.99	42.59	9.55	0.019	-2.05	-1.02
Namibia	7.97	31.02	11.76	-0.195	-3.044	-0.86
Rwanda	6.02	21.73	5.08	0.48	1.32	-0.44
South Africa	13.57	34.64	14.29	-0.45	-4.03	-0.85
Swaziland	11.895	6.65	2.29	0.14	-0.97	-0.97
Tanzania	14.94	51.55	12.97	-0.10	-2.14	-0.899
Uganda	15.20	55.95	11.46	0.18	-0.457	-0.58
Zambia	15.49	41.56	13.54	1.25	8.04	0.24
Zimbabwe	10.59	29.86	8.19	0.396	1.29	-0.46
Mean	13.28	37.092	10.84	0.22	-0.62	-0.83

Table A.25: Percentage point change in trade patterns with China ports. Fixed effects estimation approach

Partner	Agriculture	Manufacturing	Resources
Angola	0.62	2.74	1.62
Asia	3.88	17.06	10.08
Botswana	1.12	4.897	2.89
Burundi	0.98	4.32	2.16
Congo, Dem. Rep.	0.85	4.43	2.62
Kenya	0.744	3.27	1.93
Lesotho	0.322	2.03	1.035
Malawi	0.783	3.44	2.03
Mozambique	0.11	0.48	0.28
Namibia	0.15	0.64	0.38
Rwanda	0.63	2.78	1.64
South Africa	0.52	2.29	1.35
Swaziland	0.599	2.63	1.55
Tanzania	0.14	0.598	0.353
Uganda	0.92	4.06	2.40
Zambia	1.34	5.90	3.49
Zimbabwe	1.14	5.02	2.97
Total	1.28	5.71	3.34

Table A.26: Percentage point change 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 A.27: Percentage point change 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

Figure A.1: Estimating the multi-sector gravity constants

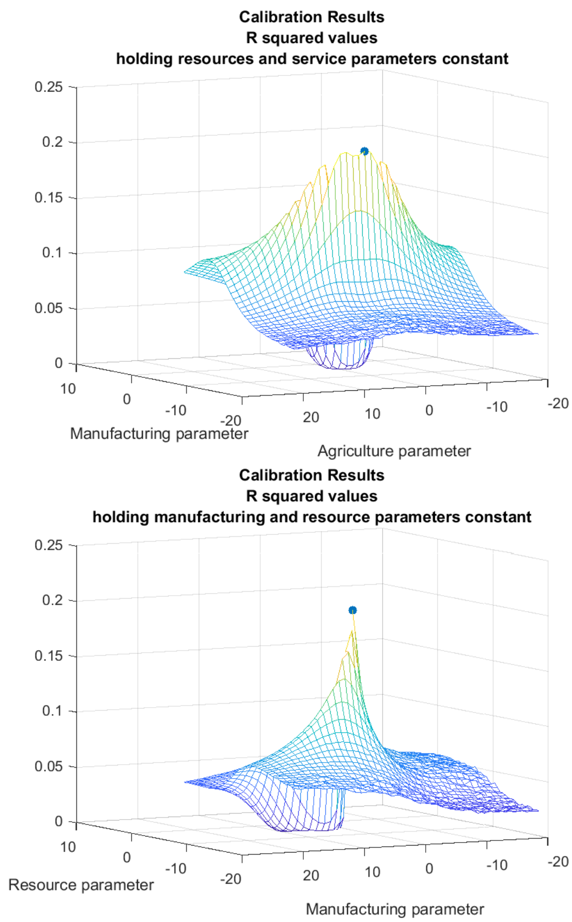


Table A.28: Growth of trade flows from infrastructure changes: Exogenous border instrument

	(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
R^2	0.446	0.446	0.450	0.450

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 A.29: Growth of trade flows from infrastructure changes using Pseudo Poisson Maximum Likelihood estimation: Excluding products that use air transport

	(1)	(2)	(3)	(4)
Symmetric Border Wait Time (log)	-0.268***	-0.173***	-0.0988***	-0.104***
	(-32.13)	(-17.20)	(-10.58)	(-10.88)
Tariffs (log)		-0.172***	-0.0399***	-0.0895***
		(-22.44)	(-4.74)	(-11.43)
Border-Road Time Interaction			-0.193***	
			(-31.07)	
Border-Distance Interaction				-0.178***
				(-29.32)
N	14847	9926	9926	9926
R^2	0.653	0.705	0.739	0.734

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.

A.2 Model Details

A.2.1 Single Sector Setup with Comparative Statics

To set up the universal gravity 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, 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 $K_{ij} > 0$. This represents the trade costs that are associated in trading between both locations such as, distance, time taken and tariffs. 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 et al. (2014) (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 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) 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 a variety of trade models.

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

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

For example in the Eaton and Kortom model the import shifters would be the income and competitiveness of locations around location i and the export shifters would be the productivity and wages of the exporting location. This equation was first introduced by Tinbergen (1962) and has gained significant empirical traction over the years.

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 $i \in S$,

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

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 $i \in S$,

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

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

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

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.

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.

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

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

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

and

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

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

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

Therefore, Allen et al. (2014) state that for any given gravity constants (α and β), income shifter $\{B_i\}$ and the bilateral trade frictions $\{K_{ij}\}$, the solution to the general equilibrium gravity model is defined by the set of export shifters γ_i and shifters δ_i that satisfy equations A.6, A.7 and A.8.

A.2.2 Single Sector Comparative Statics

To see how trade frictions affect welfare and trade flows in the model, I take advantage of the work done by Allen et al. (2014) who derive comparative statics 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 bilateral trade frictions between any two locations.

As in Allen et al (2014) let, X be an NxN matrix of observable trade flows where each $< i, j >$th element is X_{ij} and let 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

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

where **A** is obtained from implementing the implicit function theorem on equations A.3 and A.2 which can be seen in appendix A.1. 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. (2014) 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 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 on l's income can be expressed as

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

A.2.3 Comparative Statics and Calibration for Multi Sector Model

Comparative Statics

To calculate the comparative statics 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:

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

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

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

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

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

and

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

To determine the value of c, I use the world income assumption in condition 5 [1] which implies:

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

$$\sum_l Y_l \Big(\alpha \frac{\partial \gamma_l}{\partial K^s_{ij}} + \sum_{s'} \beta \theta_{s'} \frac{\partial \delta^{s'}_l}{\partial K^s_{ij}} \Big) = 0$$

Therefore

$$c^s_{ij} \equiv \frac{1}{Y^W(\alpha + \beta \sum_{s'} \theta_{s'})} X^s_{ij} \sum_l Y_l(\alpha(A^+_{l,i} + A^+_{l,N+j}) + \sum_{s'} \beta(A^+_{(s'N+l),i} + A^+_{(s'N+l),N+j}))$$

A.2.4 Solving Model for Counterfactuals

In 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.

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. [2] 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 A.6 and A.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 A.6, A.7, and A.8 found in section A.1 can be rewritten as

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

[2] 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.

$$x_i = \sum_j K_{ij} B_j^{\frac{1}{1-\alpha-\beta}} x_j^{\frac{\alpha}{\alpha+\beta-1}} y_j^{\frac{1-\alpha}{\alpha+\beta-1}} \tag{A.9}$$

and

$$y_i = \sum_j K_{ji} B_j^{\frac{1}{1-\alpha-\beta}} x_j^{\frac{1-\beta}{\alpha+\beta-1}} y_j^{\frac{\beta}{\alpha+\beta-1}} \tag{A.10}$$

with the world income set to 1 as the numeraire

$$1 = \sum_i B_i^{\frac{1}{1-\alpha-\beta}} x_i^{\frac{\alpha}{\alpha+\beta-1}} y_i^{\frac{\beta}{\alpha+\beta-1}}. \tag{A.11}$$

Allen et al 2014 show that to solve x_i and y_i we can transform equations A.9 and A.10 into a general framework which has the property of having a unique fixed point. It can be shown using Schauder's fixed point theorem that for any positive F and H, and a, b, c there exists a solution to

$$x_i = \frac{\sum_j F_{i,j} x_j^a y_j^b}{\sum_{i,j} F_{i,j} x_j^a y_j^b} \tag{A.12}$$

$$y_i = \frac{\sum_j H_{i,j} x_j^c y_j^d}{\sum_{i,j} H_{i,j} x_j^c y_j^d} \tag{A.13}$$

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

$$\tilde{x}_i = \frac{\sum_j K_{ij} B_j^{\frac{1}{1-\alpha-\beta}} \tilde{x}_j^{\frac{\alpha}{\alpha+\beta-1}} \tilde{y}_j^{\frac{1-\alpha}{\alpha+\beta-1}}}{\sum_{i,j} K_{ij} B_j^{\frac{1}{1-\alpha-\beta}} \tilde{x}_j^{\frac{\alpha}{\alpha+\beta-1}} \tilde{y}_j^{\frac{1-\alpha}{\alpha+\beta-1}}} \tag{A.14}$$

and

$$\tilde{y}_i = \frac{\sum_j K_{ji} B_j^{\frac{1}{1-\alpha-\beta}} \tilde{x}_j^{\frac{1-\beta}{\alpha+\beta-1}} \tilde{y}_j^{\frac{\beta}{\alpha+\beta-1}}}{\sum_{i,j} K_{ji} B_j^{\frac{1}{1-\alpha-\beta}} \tilde{x}_j^{\frac{1-\beta}{\alpha+\beta-1}} \tilde{y}_j^{\frac{\beta}{\alpha+\beta-1}}} \tag{A.15}$$

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

$$s = \left(\sum_{i,j} K_{i,j} B_j^{\frac{1}{1-\alpha-\beta}} x_j^{\frac{\alpha}{\alpha+\beta-1}} y_j^{\frac{1-\alpha}{\alpha+\beta-1}} \right)^{\frac{1}{1-\frac{\alpha}{\alpha+\beta-1}}} \quad \text{(A.16)}$$

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

$$t = \left[\sum_i B_i^{\frac{1}{1-\alpha-\beta}} (x_i)^{\frac{\alpha}{\beta+\alpha-1}} (y_i)^{\frac{\beta}{\beta+\alpha-1}} \right]^{-\frac{1-\beta}{\alpha-\beta}} \quad \text{(A.17)}$$

Then $(\bar{x_i}, \bar{y_i}) = \left(t^{\frac{\alpha-1}{1-\beta}} x_i, t y_i\right)$ satisfies (A.6) (A.7) and (A.8).[3]

Multi Sector Case

The strategy for solving the multi sector model follows the same strategy as the single sector model. Again as in Allen et al (2014), I can redefine the system of equations found above 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

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

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

$$y_i^s = \sum j K_{ji}^s (B_i^s)^{-1} (B_j)^{-\frac{1}{1-\alpha}} (x_j)^{\frac{1}{\alpha-1}} (y_j^s)^{-1} (z_j)^{\frac{\beta}{(\alpha-\beta)(\alpha-1)}}$$

$$z_i = \prod_s \left((y_i^s)^{\theta^t}\right)^{\alpha-\beta}$$

Where

$$\sum_{i,s,j} (B_j) K_{ij}^s (B_j)^{-\frac{\alpha}{1-\alpha}} (x_j)^{\frac{\alpha}{\alpha-1}} (y_j^{8s})^{-1} (z_j)^{\frac{\beta}{(\alpha-\beta)(\alpha-1)}} = 1$$

A.3 Identification

A.3.1 Reverse Causality

Much of the border friction arises from the presence of too many trucks (or too much trade flow) for a given amount of infrastructure. As an example, if a country had an exogenous shock of 10% to trade flows resulting in a 1% increase in wait times at the border, this would lead to a large downward bias and over estimation of the effect of wait times on trade flows.

Mathematical Description

Take from the gravity model the gravity equation that describes bilateral trade flows between country pairs.

$$X_{ij} = K_{ij}(\gamma_i)(\delta_j) \tag{A.18}$$

where (γ_i) and (δ_j) are the exporting and importing capacity (or shifters) respectively. K_{ij} represents the (unobserved) trade frictions between country pair i and j. Many papers provide methods to back out these trade frictions from either observed trade flows (of which can be done in this model), by using differences in prices across geographical space and taking advantage of no arbitrage conditions or by trying to observe trade costs directly by using proxies such as wait times, quality of roads indices, distance (if it is cross sectional), etc.

In my paper I represent the unobserved trade functions as

$$lnK_{ij} = T_{ij}\mu + \epsilon_{ij} \tag{A.19}$$

where T_{ij} is the vector of observable trade costs. I claim that T_{ij} can be represented by the amount of time it takes to get to j from i. In my study region there are three main geographical obstacles that must be accounted for. These are road travel, going across a border (sometimes many) and using ports for sea transport. Looking only at African trade, this can be reduced to just borders and road travel (although I can and do allow for trade by sea if that is indeed cheaper to do so). This could then be written as

$$T_{ij} = ln(BorderTime_{ij}(\tilde{X}_{ij}) + RoadTime_{ij}(\tilde{X}_{ij})) + \nu_{ij} \tag{A.20}$$

$$\tilde{X_{ij}} = \sum_{n}\sum_{m} X_{nm}| \text{ n and m use same route i and j do.} \tag{A.21}$$

As we can see from equations A.20 and A.21 that border and road time can increase due to traffic congestion which arises directly from the trade flows that pass through these locations. For roads,have a large impact on time costs. Not accounting for this reverse causality would lead to biased estimates of μ. Next, I will propose a method to account for this endogeneity and isolate the effects of trade frictions (due to travel times) on trade flows. Past literature has demonstrated that road quality affects the speed at which you can drive but that trucks will go certain speeds regardless to save on fuel, meaning that for most of the travel, congestion on roads due to trade flows is not significant.[4]

Possible Solution: Reverse Causality Check

One solution is to check for reverse causality by looking at the individual effects of trade flows on the border wait times by creating a measure that is independent of policy decisions and investment made during that time period.

To check for reverse causality running a regressions such as

$$BorderTime_{ijt} = \sum_{c\in\Omega_{ij}} (B_c) = \beta_0 + \beta_1 X_{ijt} + \epsilon_{ijt} \tag{A.22}$$

[4]A potential second order concern would be that higher trade flows leads to more wear on the roads, reducing the quality and subsequently the speed. But this effect takes a longer time to happen.

where Ω_{ij} is the set of borders required to go from i to j using the shortest timed path, would lead to the same endogenous issues that we had before since our main hypothesis is that border times affects trade flows.

One way to get around this is by creating a Bartik instrument for each bilateral pair i and j such that

$$\bar{X}_{ijt} = \frac{X_{ij,t-1}}{\sum_{j\in -i} X_{ij,t-1}} \sum_{j\in -i} X_{ij,t}. \tag{A.23}$$

Equation A.23 predicts what trade flows would have been if the share of trade between i and j had stayed at historical levels.[5] Two benefits of this instrument are that it is independent of trade flows between i and j (since we exclude i from the summation) and that it is unrelated to any changes in policy or investments made by i and j.

For the first step we can regress [6] our Bartik measure on observed trade flows such that

$$lnX_{ijt} = \beta_0 + \beta_1 ln\bar{X}_{ijt} + \gamma_{it} + \delta_{jt} + \epsilon_{ijt}, \tag{A.24}$$

where γ_{it}, δ_{jt} are exporter year and importer year fixed effects respectively.

With this we take the predicted values from equation A.24 and use this as the instrumental variable for

$$BorderTime_{ijt} = \sum_{c\in\Omega_{ij}} (B_{ct}) = \alpha_0 + \alpha_1(\hat{\gamma}_1 ln\bar{X}_{ijt}) + \gamma_{it} + \delta_{jt} + \epsilon_{ijt}. \tag{A.25}$$

α_1 will show the extent to which changes in trade flows relate to border wait times. If this measure is statistically significant than there would be evidence that single bilateral trade flows have a non-zero impact on border congestions and wait times leading to biased estimates of the main regression.

A.3.2 Comparing Calibration Techniques: First Order Approximation versus Solved Model Approach

As mentioned in section 5.2, calibrating parameters used in the general equilibrium model such that

[5] In equation A.23 it just has last year's shares to represent historical levels. However, this can be extended to take the average over many years prior to 2008 back to around 2001.

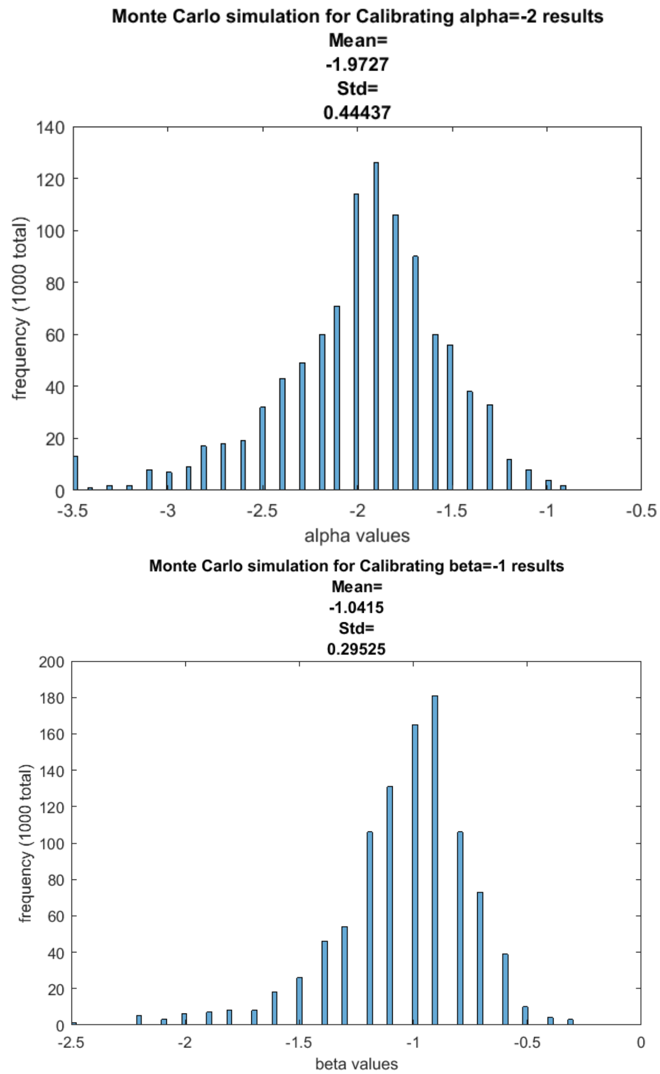
[6] The regression would be in long difference between 2008 and 2014.

$$(\alpha^*, \beta^*, \theta_1^*, \dots, \theta_s^*, \mu^{1*}, \dots, \mu^{s*}) = arg \min_{\alpha,\beta \in \mathbb{R}, \mu \in \mathbb{R}^S}$$

$$\sum_s \sum_i \sum_j \left(\ln \hat{X_{ij}^s}^{observed} - \ln \hat{X_{ij}^s}^{predicted} \right)^2. \tag{A.26}$$

holds by solving the model for each iteration is computationally intensive. This section analyzes the reliability of using the first order approximation approach outlined in Allen et al. (2014). This exercise is done by conducting Monte Carlo simulations where the parameters of the model are known prior. The simulated data is generated by creating a transportation friction dataset and solving the model for trade flows using the model parameters. I then add an error terms to both the trade friction matrix and the generated trade flow data and calibrate the model. Lastly, I perform a grid search method, once with the first order approximation technique and again with solving the model. This is done for 1000 iterations. Figure A.2 shows the results with an added error term such that the average trade flow and transportation friction is 5% different from the actual values. The average values of the parameters lie close to the real values assigned and 95% of estimates laying less than one unit from the actual value.

Figure A.2: 5 percent error terms for both trade flows and transport frictions



APPENDIX B

APPENDIX FOR CHAPTER 2: THE EFFECT OF COMMODITY PRICES AND MINES ON SPATIAL DEVELOPMENT: EVIDENCE FROM SATELLITE DATA

Section B.1 of this appendix provides additional tables for the main analysis and robustness checks. Section B.2 includes additional results.

B.1 Additional Tables

Table B.1: Effect of commodity price and resource abundance on light growth: long term effects

	(1)	(2)	(3)	(4)
lag(1) log difference in light	-0.380***	-0.380***	-0.380***	-0.402***
	(-405.09)	(-405.01)	(-404.99)	(-399.56)
large mine x log diff in price	0.0143	0.0155	0.0129	0.00956
	(0.34)	(0.37)	(0.31)	(0.23)
medium mine x log diff in price	-0.0717*	-0.0793**	-0.0830**	-0.0891**
	(-1.80)	(-1.99)	(-2.07)	(-2.23)
small mine x log diff in price	-0.175***	-0.188***	-0.193***	-0.198***
	(-5.72)	(-6.14)	(-6.24)	(-6.44)
gov't mine x log diff in price	-0.261***	-0.265***	-0.267***	-0.261***
	(-6.20)	(-6.28)	(-6.33)	(-6.24)
large mine x lag(1) log diff in price		-0.00247	-0.00282	0.00308
		(-0.06)	(-0.07)	(0.07)
medium mine x lag(1) log diff in price		0.0743*	0.0752*	0.0694*
		(1.87)	(1.89)	(1.73)
small mine x lag(1) log diff in price		0.169***	0.170***	0.160***
		(5.50)	(5.54)	(5.18)
gov't mine x lag(1) log diff in price		0.139***	0.139***	0.130***
		(3.31)	(3.30)	(3.10)
large mine x lag(2) log diff in price			-0.0140	-0.0258
			(-0.34)	(-0.61)
medium mine x lag(2) log diff in price			-0.0303	-0.0232
			(-0.77)	(-0.57)
small mine x lag(2) log diff in price			-0.0544*	-0.0524*
			(-1.80)	(-1.69)
large mine x lag(3) log diff in price				0.00525
				(0.13)
medium mine x lag(3) log diff in price				-0.0558
				(-1.42)
small mine x lag(3) log diff in price				-0.108***
				(-3.60)
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	892164	892164	892164	845208
R^2	0.365	0.368	0.371	0.375

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table B.2: Effect of commodity price and resource abundance on light growth: By iron copper and tin

	(1)	(2)	(3)	(4)
iron mine x log diff in price	0.0139	-0.00302	0.0585	0.0512
	(0.46)	(-0.08)	(1.44)	(1.19)
copper mine x log diff in price	-0.108***	-0.0842**	-0.0960**	-0.236***
	(-3.08)	(-2.13)	(-2.40)	(-5.74)
tin mine x log diff in price	-0.126**	-0.123*	-0.104*	-0.210***
	(-2.02)	(-1.96)	(-1.65)	(-3.15)
iron mine x lag(1) log diff in price		-0.0149	0.198***	0.197***
		(-0.36)	(4.07)	(3.72)
copper mine x lag(1) log diff in price		0.0490	0.0392	0.117**
		(1.05)	(0.77)	(2.37)
tin mine x lag(1) log diff in price		0.0204	0.169***	0.292***
		(0.79)	(2.79)	(4.80)
iron mine x lag(2) log diff in price			0.269***	0.518***
			(7.29)	(12.53)
copper mine x lag(2) log diff in price			0.0416	-0.153***
			(0.86)	(-3.01)
tin mine x lag(2) log diff in price			-0.173***	-0.495***
			(-2.68)	(-6.12)
iron mine x lag(3) log diff in price				0.396***
				(9.35)
copper mine x lag(3) log diff in price				0.0442
				(0.84)
tin mine x lag(3) log diff in price				0.287***
				(3.73)
District fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
Observations	939120	939120	939120	892164

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table B.3: Effect of commodity price and resource abundance on light growth: By aluminum, coal and zinc

	(1)	(2)	(3)	(4)
aluminum mine x log diff in price	-0.0245	-0.0520	-0.1000	-0.260***
	(-0.33)	(-0.58)	(-1.11)	(-2.99)
coal mine x log diff in price	0.123	0.158	0.191	0.164
	(0.96)	(1.18)	(1.39)	(1.16)
zinc mine x log diff in price	-0.0986***	-0.0940**	-0.0825**	-0.0561
	(-2.87)	(-2.51)	(-2.08)	(-1.45)
aluminum mine x lag(1)log diff in price		-0.0458	0.206**	0.438***
		(-0.58)	(2.24)	(4.75)
coal mine x lag(1)log diff in price		0.0673	0.172	0.150
		(0.82)	(1.24)	(1.01)
zinc mine x lag(1)log diff in price		0.00803	-0.00527	0.0308
		(0.28)	(-0.15)	(0.82)
aluminum mine x lag(2)log diff in price			0.428***	0.670***
			(5.40)	(7.19)
coal mine x lag(2)log diff in price			-0.113	-0.143
			(-0.82)	(-0.96)
zinc mine x lag(2)log diff in price			0.0261	0.0863
			(0.68)	(1.64)
aluminum mine x lag(3)log diff in price				0.330***
				(4.24)
coal mine x lag(3)log diff in price				0.0591
				(0.38)
zinc mine x lag(3)log diff in price				-0.116***
				(-3.06)
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
Observations	939120	939120	939120	892164

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table B.4: Effect of commodity price and resource abundance on light growth: By gold, silver and nickel

	(1)	(2)	(3)	(4)
gold mine x log diff in price	-0.163***	-0.179***	-0.158***	-0.125***
	(-7.95)	(-7.90)	(-6.59)	(-5.38)
silver mine x log diff in price	0.395***	0.406***	0.395***	0.273***
	(9.27)	(9.38)	(9.06)	(6.35)
nickel mine x log diff in price	-0.152***	-0.197***	-0.202***	-0.226***
	(-2.95)	(-3.56)	(-3.62)	(-3.84)
gold mine x lag(1)log diff in price		-0.0266	-0.0675***	0.0167
		(-1.49)	(-3.05)	(0.72)
silver mine x lag(1)log diff in price		-0.00870	0.116**	0.0132
		(-0.62)	(2.40)	(0.28)
nickel mine x lag(1)log diff in price		-0.0670**	-0.0421	0.0731
		(-2.11)	(-0.79)	(1.37)
gold mine x lag(2)log diff in price			0.0665***	0.0919***
			(2.86)	(2.93)
silver mine x lag(2)log diff in price			-0.148***	-0.264***
			(-2.82)	(-4.05)
nickel mine x lag(2)log diff in price			-0.0324	-0.129*
			(-0.61)	(-1.75)
gold mine x lag(3)log diff in price				-0.121***
				(-5.21)
silver mine x lag(3)log diff in price				0.322***
				(4.89)
nickel mine x lag(3)log diff in price				0.0328
				(0.57)
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
Observations	939120	939120	939120	892164

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table B.5: Effect of commodity price and resource abundance on light growth: Institutions

	(1)	(2)	(3)	(4)
mine x growth in price (ln)	-0.180***	-0.200***	-0.195***	-0.209***
	(-13.21)	(-12.53)	(-12.09)	(-12.78)
bureaucratic quality x mine x growth in prices (ln)		0.00169	0.00200	0.00247
		(0.65)	(0.77)	(0.95)
bureaucratic quality x mine x growth in prices (ln)		-0.00419***	-0.00402***	-0.00455***
		(-3.60)	(-3.45)	(-3.90)
Law and Order x mine x growth in prices (ln)		0.00378***	0.00457***	0.00284***
		(5.55)	(6.44)	(3.77)
Law and Order x mine x lag(1) growth in prices (ln)		0.00426***	0.00427***	0.00392***
		(4.50)	(4.50)	(4.13)
corruption x mine x growth in prices (ln)		-0.00624***	-0.00608***	-0.00680***
		(-9.59)	(-9.09)	(-9.99)
corruption x mine x lag(1) growth in prices (ln)		-0.00335***	-0.00322***	-0.00331***
		(-3.45)	(-3.31)	(-3.40)
gov't stability x mine x growth in prices (ln)			-0.000200	0.000207
			(-1.23)	(1.23)
internal conflict x mine x growth in prices (ln)			-0.00125***	-0.00221***
			(-4.15)	(-6.91)
Accountability x mine x growth in prices (ln)			0.000653	0.000508
			(1.55)	(1.18)
ethnic tension x mine x growth in prices (ln)				-0.000725
				(-1.23)
external conflict x mine x growth in prices (ln)				0.00219***
				(7.00)
military control x mine x growth in prices (ln)				-0.000263
				(-0.58)
religious control x mine x growth in prices (ln)				0.00453***
				(7.20)
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	574056	550948	550948	550948

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table B.6: Effect of commodity price and resource abundance on light growth: Spillover effects and local effects on cities/capitals

	(1)	(2)	(3)	(4)
mine x growth in price (ln)	-0.121***	-0.0877***	-0.0951***	-0.0952***
	(-7.85)	(-5.38)	(-4.69)	(-4.70)
mine x lag(1) growth in price (ln)	0.135***	0.0669***	0.0669***	0.0712***
	(8.88)	(4.16)	(4.16)	(3.56)
adjacent mine x growth in price (ln)		-0.0636***	-0.0638***	-0.0637***
		(-7.28)	(-7.29)	(-7.29)
adjacent mine x lag(1) growth in price (ln)		0.117***	0.117***	0.117***
		(13.56)	(13.56)	(13.56)
mine x growth of price x country capital			-0.0250	-0.0229
			(-0.18)	(-0.17)
mine x growth of price x state capital			0.0267	0.0262
			(0.51)	(0.50)
mine x growth of price x large city			0.0162	0.0166
			(0.49)	(0.50)
mine x lag(1) growth in price (ln) x country capital				-0.0992
				(-0.74)
mine x lag(1) growth in price (ln) x state capital				0.0313
				(0.61)
mine x lag(1) growth in price (ln) x large city				-0.0189
				(-0.58)
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	939120	939120	939120	939120

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table B.7: Institution Clusters

Total				
		Mean	Std	
	Bureaucratic Quality	2.16	1.25	
	Law and Order	3.9	1.31	
	Corruption	2.96	1.32	
Cluster 1				
		Mean	Std	Std's away from the mean
	Bureaucratic Quality	2.08	0.474	-0.06
	Law and Order	2.95	0.677	-0.73
	Corruption	3.01	0.64	0.04
Cluster 2				
		Mean	Std	Std's away from the mean
	Bureaucratic Quality	3.5	0.474	1.07
	Law and Order	5.23	0.677	1.02
	Corruption	4.57	0.64	1.22
Cluster 3				
		Mean	Std	Std's away from the mean
	Bureaucratic Quality	0.71	1.08	-1.16
	Law and Order	2.15	0.81	-1.34
	Corruption	1.55	0.88	-1.07
Cluster 4				
		Mean	Std	Std's away from the mean
	Bureaucratic Quality	1.73	0.5	-0.34
	Law and Order	4.3	0.58	0.31
	Corruption	2.22	0.59	-0.56

Source: International Country Risk Guide (ICRG). Clusters were determined by countries' bureaucratic quality, level of corruption and rule of law measures.

Table B.8: Institutional Clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Australia	Argentina	Angola	Albania
Austria	Botswana	Burkina Faso	Algeria
Belgium	Brazil	El Salvador	Bangladesh
Brunei	Bulgaria	Ethiopia	Bolivia
Chile	Cameroon	Guinea	Colombia
Denmark	China	Guinea-Bissau	Guatemala
Finland	Costa Rica	Guyana	Haiti
Germany	Cuba	Indonesia	Honduras
Hungary	Dominican Republic	Malawi	Iraq
Iceland	Ecuador	Mali	Kenya
Iran	Egypt	Myanmar	Liberia
Italy	Gabon	Nicaragua	Madagascar
Japan	Gambia	Panama	Niger
Luxembourg	Ghana	Peru	Nigeria
Namibia	Greece	Romania	Paraguay
Netherlands	India	Sierra Leone	Somalia
New Zealand	Jordan	Suriname	Sudan
Norway	Malaysia	Tanzania	
Portugal	Mexico	Togo	
South Africa	Mongolia	Uganda	
South Korea	Morocco	Uruguay	
Spain	Mozambique	Vietnam	
Sweden	Oman	Zambia	
Switzerland	Pakistan		
Turkey	Papua New Guinea		
United Kingdom	Poland		
United States	Russia		
	Senegal		
	Sri Lanka		
	Syria		
	Taiwan		
	Thailand		
	Tunisia		
	Venezuela		
	Yemen		
	Zimbabwe		

Source: International Country Risk Guide (ICRG). Clusters were determined by countries' bureaucratic quality, level of corruption and rule of law measures.

Table B.9: Conflict Clusters

Total				
		Mean	STD	
	Internal Conflict	9.52	2.16	
	External Conflict	10.17	1.81	
	Ethnic Tension	4.15	1.29	
Cluster 1				
		Mean	STD	STDs away from the mean
	Internal Conflict	11.17	2.25	0.76
	External Conflict	11.31	1.31	0.63
	Ethnic Tension	4.69	1.65	0.42
Cluster 2				
		Mean	STD	STDs away from the mean
	Internal Conflict	5.84	0.83	-1.70
	External Conflict	5.61	0.71	-2.52
	Ethnic Tension	2.89	0.9	-0.98
Cluster 3				
		Mean	STD	STDs away from the mean
	Internal Conflict	9.8	1.71	0.13
	External Conflict	9.48	1.1	-0.38
	Ethnic Tension	5	0.85	0.66
Cluster 4				
		Mean	STD	STDs away from the mean
	Internal Conflict	7.78	1.03	-0.81
	External Conflict	10.46	1.01	0.16
	Ethnic Tension	2.88	0.74	-0.98

Source: International Country Risk Guide (ICRG). Clusters were determined by countries' level of internal conflict, external conflict and ethnic tension.

Table B.10: Conflict clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Argentina	Angola	Albania	Algeria
Australia	Colombia	Belarus	Bangladesh
Austria	Guinea	Bulgaria	Bolivia
Belgium	India	Burkina Faso	Brazil
Botswana	Iraq	Chile	Cameroon
Brunei	Liberia	Costa Rica	Ecuador
China	Nigeria	Croatia	Gabon
Czech Republic	Pakistan	Cuba	Guatemala
Denmark	Somalia	Dominican Republic	Guinea-Bissau
Finland	Sudan	Egypt	Haiti
Gambia	Uganda	El Salvador	Indonesia
Germany	Zimbabwe	Ethiopia	Kenya
Ghana		Greece	Latvia
Guyana		Honduras	Madagascar
Hungary		Iran	Mozambique
Iceland		Italy	Myanmar
Luxembourg		Japan	Namibia
Malawi		Jordan	Niger
Malaysia		Morocco	Paraguay
Mali		Nicaragua	Peru
Mexico		Oman	Russia
Mongolia		Panama	Senegal
Netherlands		South Korea	Sierra Leone
New Zealand		Syria	Spain
Norway		Thailand	Sri Lanka
Papua New Guinea		Uruguay	Togo
Poland		Yemen	Turkey
Portugal		Zambia	Ukraine
Romania			
Slovakia			
Slovenia			
South Africa			
Suriname			
Sweden			
Switzerland			
Taiwan			
Tanzania			
Tunisia			
United Kingdom			
Venezuela			
Vietnam			

Source: International Country Risk Guide (ICRG). Clusters were determined by countries' level of internal conflict, external conflict and ethnic tension.

Table B.11: Effect of commodity price and resource abundance on light growth: Ownership and size of mines

	(1)	(2)	(3)	(4)
lag (1) log diff in sum light	-0.380***	-0.380***	-0.380***	-0.380***
	(-405.13)	(-405.13)	(-405.09)	(-405.09)
mine x log diff in price	-0.175***	-0.162***		
	(-12.29)	(-11.18)		
gov't mine x log diff in price		-0.204***		-0.261***
		(-4.78)		(-6.20)
large mine x log diff in price			0.00225	0.0143
			(0.05)	(0.34)
medium mine x log diff in price			-0.0845**	-0.0717*
			(-2.13)	(-1.80)
small mine x log diff in price			-0.180***	-0.175***
			(-5.87)	(-5.72)
District fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	892164	892164	892164	892164

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table B.12: Effect of commodity price and resource abundance on light growth: Size and development state of resources

	(1)	(2)	(3)	(4)
present large mine x growth in price (ln)	0.00981			0.0263
	(0.21)			(0.53)
present medium mine x growth in price (ln)	-0.0685			-0.0554
	(-1.51)			(-1.16)
present small mine x growth in price (ln)	-0.125***			-0.101**
	(-3.58)			(-2.25)
future large mine x growth in price (ln)		-0.00802		0.0293
		(-0.12)		(0.41)
future medium mine x growth in price (ln)		-0.0769		-0.0142
		(-1.30)		(-0.22)
past small mine x growth in price (ln)		-0.0882**		-0.0318
		(-2.51)		(-0.70)
future large mine x growth in price (ln)			-0.0877	-0.0711
			(-1.13)	(-0.88)
future medium mine x growth in price (ln)			-0.0836	-0.0540
			(-1.20)	(-0.74)
future small mine x growth in price (ln)			-0.0901**	0.0167
			(-2.43)	(0.31)
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	939120	939120	939120	939120

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table B.13: Effect of commodity price and resource abundance on light growth: Size and development state with lags

	(1)	(2)	(3)	(4)
present large mine x lag(1) growth in price (ln)	0.00742			0.00850
	(0.16)			(0.17)
present medium mine x lag(1) growth in price (ln)	0.0892**			0.0983**
	(2.01)			(2.09)
present small mine x lag growth in price (ln)	0.106***			0.0989**
	(3.10)			(2.25)
future large mine x lag(1) growth in price (ln)		-0.00254		-0.0545
		(-0.04)		(-0.77)
future medium mine x lag(1) growth in price (ln)		0.0169		-0.0578
		(0.29)		(-0.91)
past small mine x lag(1) growth in price (ln)		0.115***		0.0658
		(3.34)		(1.48)
future large mine x lag(1) growth in price (ln)			0.0454	0.0284
			(0.60)	(0.36)
future medium mine x lag(1) growth in price (ln)			0.102	0.0785
			(1.48)	(1.09)
future small mine x lag(1) growth in price (ln)			0.0752**	-0.0512
			(2.07)	(-0.98)
District fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Excluding US and China	Yes	Yes	Yes	Yes
N	939120	939120	939120	939120

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

B.2 Additional Analysis

B.2.1 Asymmetric Effects

To allow for possible asymmetries of price effects, I split ΔP_{t-1} into two groups. Let

$$\Delta P_{t-1}^{+} = max[0, \Delta P_{t-1}].$$

$$\Delta P_{t-1}^{-} = min[0, \Delta P_{t-1}].$$

I can then rewrite equation 2 as

$$\Delta y_{i,t} = \beta_1(\Delta P_{t-1}^{+} * M_i^{tot}) + \beta_2(\Delta P_{t-1}^{-} * M_i^{tot}) + \tilde{\phi}_{c,t} + \Delta\epsilon_{i,t}. \quad \text{(B.1)}$$

Appendix Table B.14 splits prices into positive and negative growth periods. Positive price changes see a consistent negative relationship especially short term. However there appears to be evidence for a positive relationship when looking at negative price changes. Using column 9 we see that the lagged negative price changes have a higher magnitude effect on light growth than lagged positive price changes. One explanation for this is that when prices increase, part of the revenue from mining activity goes to major metropolitan areas as suggested by (Galina 2014). The remainder is distributed to miners and and other operators located in populated areas close to the mine but this too could leave the mining cities since many miners relocate and send money back to their prior location where they will return to. However when prices fall it may lead to mass lay offs that affect how many people are living in these communities near mining areas.

B.2.2 Alternate Spillover Measure

A third method of measuring spillover effects adds the number of resource areas together but discounts the resource area with respect to the distance between the district of interest and the resource location such that

$$ResourceAccess_i = \sum_{j \in S} \frac{Res_j}{Dist_{ij}}.$$

To check if this method provides additional benefits over the state wide spillover method, I calculate the resource access for Canada and provide regression analysis to compare the two. Appendix Table B.15 shows that both methods provide similar results. Therefore, since there are nearly 47,000 district within my

Table B.14: Growth of total light from price changes and resource abundance: Aggregated Resource with positive and negative price change measures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
logMine×PosPrice Lag1	-0.00868***	-0.00868***	-0.00878***	-0.00428***	-0.00435***	-0.00437***	-0.00536***	-0.00529***	-0.00510***
	(-9.25)	(-9.24)	(-9.31)	(-5.31)	(-5.38)	(-5.39)	(-5.71)	(-5.63)	(-5.42)
logMine×NegPrice Lag1	0.000115	0.000372	-0.000198	0.00352***	0.00189	0.00197	0.00440***	0.00581***	0.00794***
	(0.12)	(0.26)	(-0.13)	(4.36)	(1.54)	(1.50)	(4.69)	(3.61)	(4.57)
logMine×PosPrice Lag2		0.000465	0.0000718		-0.00215*	-0.00198		0.00152	0.00349**
		(0.33)	(0.05)		(-1.76)	(-1.53)		(0.95)	(2.04)
logMine×NegPrice Lag2		-0.000633	-0.00227		-0.000134	-0.000340		0.00121	0.00541***
		(-0.67)	(-1.51)		(-0.17)	(-0.26)		(1.29)	(3.16)
logMine×PosPrice Lag3			-0.00268*			-0.000783			0.00466***
			(-1.75)			(-0.59)			(2.69)
logMine×NegPrice Lag1			0.00251***			0.00229***			0.00269***
			(2.66)			(2.82)			(2.85)
lnSumLight Lag1				-0.499***	-0.499***	-0.498***	-0.498***	-0.498***	-0.498***
				(-593.04)	(-592.99)	(-592.87)	(-571.16)	(-571.09)	(-570.98)
Exclude China & U.S	No	No	No	No	No	No	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
N	1013410	1013158	1012906	1013410	1013158	1012906	936590	936340	936090

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

sample, the resource access method would be computationally intensive for little benefit.

Table B.15: Effect of commodity price and resource abundance on light growth: Comparing resource access measure with statewide spill over method in Canada

	(1)	(2)	(3)	(4)
mine x log diff in price	-0.0768	-0.122	-0.136	-0.127
	(-0.65)	(-0.99)	(-1.02)	(-0.94)
# state mine x log diff in price	-0.172***	-0.183***	-0.202***	-0.196***
	(-4.86)	(-5.01)	(-5.32)	(-5.01)
resource access (ln) x log diff in price	0.160	0.0217	0.0236	0.0236
	(0.02)	(0.28)	(0.28)	(0.28)
mine x lag(1) log difference in price		0.331**	0.347**	0.366**
		(2.26)	(2.21)	(2.17)
# state mine x lag(1) log diff in price		0.173***	0.193***	0.208***
		(4.17)	(4.46)	(4.64)
resource access (ln) x lag(1) log diff in price		0.177*	0.181*	0.187*
		(1.86)	(1.81)	(1.75)
mine x lag(2) log diff in price			0.0573	0.0252
			(0.61)	(0.25)
# state mine x lag(2) log diff in price			-0.876	-0.0181
			(-0.28)	(-0.55)
resource access (ln) x lag(2) log diff in price			-0.0750	-0.0635
			(-1.19)	(-0.94)
mine x lag(3) log diff in price				-0.609
				(-0.05)
# state mine x lag(3) log diff in price				-0.0433
				(-1.25)
resource access (ln) x lag(3) log diff in price				0.129
				(0.02)
N	5860	5860	5567	5274

The dependent variable is growth in log sum of light from 1992 to 2013 with mineral resources not aggregated. All estimates use country-year fixed effects and district fixed effects. t-statistics (in parentheses) allow for spatial correlation within a 1000km radius and a 20 year serial correlation. Significance levels are: * 0.10, ** 0.05, *** 0.01.

WORKS CITED FOR CHAPTER 1

[1] Akpan 2014. *Impact of Regional Road Infrastructure Improvement on Intra-Regional Trade in ECOWAS* . African Development Review, 26 (1), 64-76

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

[3] Allen, Arkolakis 2014. *Trade and the Topography of the Spatial Economy*. Quarterly Journal of Economics. 129 (3), 1085-1140

[4] Allen, Arkolakis, Takahashi 2014. *Universal Gravity*. Working Paper

[5] Anderson, Van Wincoop 2003. *Gravity with Gravitas: A Solution to the Border Puzzle*. American Economic Review 93 (1): 170-192.

[6] Armington, P. 1969. *A Theory of Demand for Products Distinguished by Place of Production* . International Monetary Fund Vol. 16, No. 1 (Mar., 1969), pp. 159-178

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

[8] Baier, Bergstrand 2001. *The growth of world trade: tariffs, transport costs, and income similarity*. Journal of International of Economics, 53 (1), 1-27

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

[10] Banerjee, Abhijit, Esther, Qian 2011. *On the Road: Access to Transport Infrastructure and Economic Growth in China*. NBER Working Paper No, 17897.

[11] Baum-Snow, Brandt, Henderson, Turner, Zhang 2011. *Roads, Railroads and Decentralization of Chinese Cities*. Review of Economics and Statistics.

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

[13] 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.

[14] Chandra, Thompson 2000. *Does Public Infrastructure Affect Economic Activity?: Evidence from the Rural Interstate Highway System*. Regional Science and Urban Economics, 30, (4), 457-490.

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

[16] Coughlin, Novy 2011. *Is the International Border Effect Larger than the Domestic Border Effect? Evidence from U.S. Trade*. University of Nottingham, GEP Research Paper 2009/29.

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

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

[19] Donaldson forthcoming. *Railroads and the Raj: Estimating the Impact of Transport Infrastructure*. American Economic Review.

[20] Donaldson, Hornbeck 2016. *Railroads and American Economic Growth: A Market Access Approach*. The Quarterly Journal of Economics, 131 (2): 799-858.

[21] Eaton, Kortum 2002. *Technology, Geography, and Trade*. Econometrica 70(5): 1741-1779.

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

[23] Frankel, Wei 1998. *ASEAN in a Regional Perspective*. Pacific Basin Working Paper Series 96-02, Federal Reserve Bank of San Francisco. ASEAN in a regional perspective,

[24] Gandhi, Duffy 2013. *Extra Border Security and its Impact on Canada-United States Trade and Investment*. Journal of Eastern Townships Studies

[25] Gandhi, Duffy 2013. *Extra Border Security and its Impact on Canada-United States Trade and Investment*. Journal of Eastern Townships Studies

[26] Head, Mayer 2013 *Gravity Equations: Workhorse,Toolkit, and Cookbook*. CEPII Working Paper

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

[28] Mbekeani 2013. *Understanding the Barriers To Regional Trade Integration In Africa* . African Development Bank Group

[29] McCallum 1996. *National Borders Matter: Canada-US Regional Trade Patterns* . American Economic Review, 85 (3), 615-623.

[30] Michaels 2008 *The Effect of Trade on The Demand for Skill: Evidence from the Interstate Highway System* . The Review of Economics and Statistics 90(4): 683-701.

[31] Millimet, Osang 2007. *Do State Borders Matter for U.S. Intranational Trade? The Role of History and Internal Migration* . Canadian Journal of Economics, 40 (1), 93-126

[32] Nitsch 2000. *National Borders and International Trade: Evidence from the European Union* . Canadian Journal of Economics,1091-1105.

[33] Obstfeld, Rogoff 2001 *The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?* . NBER Macroeconomics Annual, Volume 15

[34] Pisu and Braconier 2013. *Road Connectivity and the. Border Effect: Evidence from Europe* . OECD Economics. Department Working Paper.

[35] Parsley, Wei 2001 *Explaining the border effect: the role of exchange rate variability, shipping costs, and geography*. Journal of International Economics, 55, 87105

[36] Reggiani, Russo, Tedeschi, Nijkamp 2014 *Commuter Effects on Local Labour Markets: A German Modelling Study* . Urban Studies 51 (3), 493-508

[37] Roberts, Deichmann, Fingleton and Shi 2012 *Evaluating China's road to prosperity: A new economic geography approach*. Regional Science and Urban Economics 42: 580-594

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

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

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

[41] Storeygard 2018. *Economic and Political Factors in Infrastructure Investment: Evidence from Railroads and Roads in Africa 19602015*. Working Paper

[42] Storeygard 2016. *Farther on down the Road: Transport costs, Trade and Urban Growth in Sub-Saharan Africa*. Review of Economic Studies, 83(3): 1263-1295.

[43] Trefler 1993. *Trade Liberalization and the Theory of Endogenous Protection*. Journal of Political Economy

[44] Trefler 2004. *The Long and Short of the Canada-US Free Trade Agreement*. AER 94(4), 870-895.

[45] Wei 1996. *Intra-National Versus International Trade: How Stubborn are Nations in Global Integration*. NBER Working Paper Series, No. 5531.

WORKS CITED FOR CHAPTER 2

[1] Abubakr R., Lean H., Clark J. 2017. *The evolution of the natural resource curse thesis: A critical literature survey* . Resources Policy Volume 51, Pages 123-134

[2] Addison, Ghoshray and Stamatogiannis 2014. *Agricultural Commodity Price Shocks and Their Effect on Growth in Sub-Saharan Africa* .

[3] Allcott H. and Daniel K. 2003. *Dutch Disease or Agglomeration? The Local Economic Effects of Natural Resource Booms in Modern America*. NBER Working Paper 20508

[4] Angrist J.D., Kugler A. 2008. *Rural windfall or a new resource curse? Coca, income, and civil conflict in Colombia*.

[5] Bazzi, S. and Blattman C. 2014. *Economic Shocks and Conflict: Evidence from Commodity Prices*. American Economic Journal: Macroeconomics 6 (4): 1 - 38. Journal 116 (508): 1 - 20.

[6] Bauer A., Gankhuyag U., Halling S., Manley D., Venugopal V. 2016. *Natural Resource Revenue Sharing*. Natural Resource Governance Institute Report

[7] Berman N. Couttenier M. Rohner D. Mathias Thoenig 2017. *This Mine Is Mine! How Minerals Fuel Conflicts in Africa*. American Economic Review, Vol. 107(6) pp. 1564-1610.

[8] Borge, Parmer and Torvik 2015. *Local natural resource curse?*. Journal of Public Economics

[9] Brunnschweiler C., Bulte E. 2008. *The resource curse revisited and revised: A tale of paradoxes and red herrings*. Journal of Environmental Economics and Management, 2008, vol. 55, issue 3, 248-264

[10] Caselli F. and Michaels G. 2009. *Resource abundance, development, and living standards: evidence from oil discoveries in Brazil*. NBER Working Paper No. 1555

[11] Conley T.G. 1999. *GMM Estimation with Cross Sectional Dependence.*. Journal of Econometircs 92(1):1-45

[12] Corden M.W. and Neary P.J. 1982. *Booming sector and de-industrialisation in a small open economy*. Economic Journal, vol., 92(368), pp. 825 48.

[13] Collier P., and Goderis B. 2012. *Commodity prices and growth: An empirical investigation*. European Economic Review, 2012, vol. 56, issue 6, 1241-1260

[14] Deaton, Angus S., Miller, Ronald I. 1995. *International commodity prices, macroeconomic performance, and politics in sub-saharan africa*. Princeton Studies in International Finance 79.

[15] Domenech J. 2008. *For Mineral resource abundance and regional growth in Spain, 1860-2000*,

[16] Downes P., Hanslow K. and Tulip P. 2014. *The Effect of the Mining Boom on the Australian Economy*, Research Discussion Paper, Reserve Bank of Australia

[17] Duranton G. and Puga D. 2004. *Micro-foundations of urban agglomeration economies*. Handbook of Regional and Urban Economics, vol. 4, ch. 48, pp. 2063 117

[18] Engerman S. and Sokoloff K. 1997. *Factor Endowments, Institutions, and Differential Paths of Growth among New World Economies: A View From Economic Historians of the United States*. How Latin America Fell Behind, edited by Stephen Haber (Stanford University Press), 260-304.

[19] Guimaraes P. and Portugal P. 2010. *A Simple Feasible Alternative Procedure to Estimate Models with High-Dimensional Fixed Effects*. Stata Journal, 10(4), 628-649,

[20] Henderson V., Storeygard A., and David N . 2012. *Measuring Economic Growth from Outer Space*. American Economic Review 102(2) pp. 994-1028

[21] Hsiang, Solomon, Meng K. and Cane M. 2011. *Civil Conflicts are Associated with the Global Climate*. Nature 476: 438-41

[22] Humphreys M., Solomon, Sachs J. and Stiglitz J. 2007. *Escaping the resource curse*. ch. 2, p. 26

[23] Ivanova, G. 2014. *The mining industry in Queensland, Australia: Some regional development issues*. Resources Policy, vol. 39, issue C, 101-114

[24] John, J. 2011. *Is There Really a Resource Curse? A Critical Survey of Theory and Evidence*. Global Governance Vol. 17, No. 2, pp. 167-184

[25] Manzano O. and Rigobon R. 2007. *Resource curse or debt overhang?*. Natural resources, neither curse nor destiny (pp. 41-70).

[26] Mehlum H., Moene K., Torvik, R. 2006. *Institutions and the Resource Curse*. Economic Journal 116 (508): 1-20

[27] Michaels G. 2003. *The Long Term Consequences of Resource-Based Specialisation*. The Economic Journal 2003.

[28] Natural Earth Data. http://www.naturalearthdata.com/downloads/10m-cultural-vectors/10m-populated-places/

[29] Papyrakis E., Gerlagh R. 2007. *Resource abundance and economic growth in the United States*.

[30] Rosenthal S.S. and Strange, W.C. 2004. *Evidence on the nature and sources of agglomeration economies*. Handbook of Regional and Urban Economics, vol. 4, ch. 49, pp. 211 71

[31] Sachs J., Warner A. 1995. *Economic Convergence and Economic Policies*. NBER Working Paper No. 5039

[32] Sachs J., Warner A. 2001. *The curse of natural resources*. European Economic Review, vol. 45, issue 4-6, 827-838

[33] Sala-I-Martin and Xavier X. 1997. *I just ran two million regressions*. American Economic Review, 87 (2) (1997), pp. 178-183

[34] Sumner A., and Vazquez, T. 2014. *How Has the Developing World Changed since the Late 1990s? A Dynamic and Multidimensional Taxonomy of Developing Countries*. Center for Global Development, Working Paper 375

[35] Topp V., Soames L., Parham D. and Bloch H. 2008. *Productivity in the Mining Industry: Measurement and Interpretation*. Commonwealth of Australia Productivity Commission Staff Working Paper

[36] Watkins M. 1963. *A staple theory of economic growth*. Canadian Journal of Economic and Political Science, 29