Evaluating the Impact of Ocean and Air Infrastructure on Trade:

A Gravity Model Approach

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1. Introduction

Trade, the exchange of goods and services between two countries, has evolved with globalization. Nowadays closed economies are rare; most countries engage in some trade in manufactured goods, agricultural goods, energy, or services. Technology has allowed for greater interconnectivity among countries resulting in logistic chains scattered around the world and for producers and consumers to be in different countries. Trade has received considerable attention since it has proven to benefit both sides of the transaction and improve standards of living. The benefits for trading are countless, such as economies of scale, broader markets, cheaper inputs, and greater availability of choices for consumers; it also has taken specialization of labor a step further.

As a result, every year governments spend great amounts of money in export promotion activities and carry out detailed research trying to figure out the right level of import restrictions to protect national producers. However, trade is significantly affected by transportation costs. As competition increases for both transport companies and their customers, they seek new ways to reduce costs, and technology has played a major role. Technology has allowed the development of shorter routes for trade. First the Suez Canal emerged as a crucial link for trade between countries in Europe and the East. Later the Panama Canal was built making more efficient the trade between Asia and the East Coast of the United States and Europe. Infrastructure continues to improve every year as firms look for lower costs and wider markets. Expanded markets allowed greater exploitation of economies of scale. There also have been many improvements in the size of vessels, the capacity and strength of the motors used, and containers, which represent a stepping point. The purpose of this paper is to examine the impact of the quality of port and airport infrastructure on exports.

Understanding the impact of infrastructure on ocean and air transport costs is important for at least two reasons. First, if infrastructure is related to trade such as the better facilities the greater the trade, it could help governments decide on investment for infrastructure suitable for handling containers, vessels, and aircrafts, and facilitating access to them. Furthermore, it could help governments determine optimal combination of public and private investment. Second, if better infrastructure is related to other costs like time, red tape and crime, then an improvement would increase trade and reduce costs for exporters, making exports more competitive in the world market.

This paper will address the question by looking at the effect of infrastructure on the volume of exports using a gravity model; in other words, it will examine the trade allocation between two countries. This will be done after controlling for distance, trade barriers, GDP and countries' common socioeconomic aspects such as language and border. The second section of the paper will review the existing literature, the third section will address expectations of trade, the fourth and fifth sections will review the data and methodology used for the analysis, the sixth section will present the results, and the seventh section will conclude and identify possible limitations of the estimates.

2. Previous Literature

Most products are exported to only a few destinations; not exporting to a country is positively related with distance and negatively related to market size (Baldwin and Harrigan, 2011). The impact of distance as a contributor to the choice of products being traded is due mainly to the cost-to-value of the product, in other words, the margin of earning after trade. If the margin of earning before trade is too small the product would not be able to cover travel costs unless they raise the price at the destination. Raising the price is possible with some products; however, when this is done, the product becomes less competitive at the consuming region and therefore many products are not traded.

Reducing transportation costs would reduce the gap between the price in the producer region and the consuming region resulting in a wider range of products available for trade. The amount and quality of transport infrastructure in the producing, consuming and transit countries have a major impact on transportation costs. Clark et al (2004) used panel data for the years 1996, 1998, and 2000 and found that a significant improvement in port efficiency and infrastructure (from the 25th to the 75th percentile) reduces shipping costs by more than 12 percent and as a result increases trade by about 25 percent; however, Blonigen and Wilson (2008) found that when controlling for unobserved country-pair characteristics that could be correlated with port efficiency, the same improvement in port efficiency (from the 25th to the 75th percentile) only increases trade by 5 percent. Their study used data from 1991 to 2003, but the model was estimated separately for each year due to the large number of observations they had. Their observations amounted to more than 300 thousand per year. Nordas and Piermartini (2004) used cross country data, but only for the year 2000 and found that a 10 percent improvement in port efficiency increases trade more than 6 percent regardless if the improvement is in the importer or exporter country. And Limao and Venables (2001) with data for the 1990 said that improving from the 50th to the top 25th percentile increases trade by 68 percent, equivalent to being 2,005 km closer to trading partners, however, moving to the bottom 75th percentile reduces trade by 28 percent, equivalent to 1,627 km further from trading partners.

Blonigen and Wilson (2008) developed a ranking of ports and found that out of a 100 ports the most efficient were the European and some Asian, especially the Japanese. Ports half way down the list were in the newly industrialized countries in Southeast Asia like Taiwan and Korea, and the least efficient ports were found in Central America and China.

It is important to keep in mind that there are other factors such as trade policies, time, and reliability that also affect the trade of products. Nordas and Piermartini (2004) define trade costs as the combination of search costs, the cost of entering and enforcing contracts, transport costs, tariffs, and the costs of delays and uncertainties. Hence, countries tend to trade with countries where their business environment and customs are similar, reducing search and contracts costs.

a. Transportation costs

There are a number of papers that focus on factors that determine transportation costs in international trade. Gaulier et al. (2008) constructed a data set for transportation costs based on the UN's COMTRADE database and controlled for distance, geographic and socioeconomic aspects of the trading countries, product type, economies of scale and congestion in ports, and infrastructure. They found that not accounting for infrastructure in the equation biases distance and that better infrastructure in both countries reduces transport costs, with elasticity of .009 for the infrastructure of the exporting country and .002 for the importing country.

Hummels (2007) measures air and ocean transport costs separately. He argues that as the relative price of air/ocean shipping falls, goods shift from ocean to air shipping since the costs saved by a shorter time of travel overcome the cost saving from sending the shipment by ocean. Nevertheless, ocean shipping still constitutes the majority of world trade. Furthermore, he estimated that a 10 percent increase in distance between the producer and the destination port in the United States increases transportation costs by 2.7 percent by air and 1.5 percent by sea.

The difficulty in measuring transport costs is that good data is difficult to obtain and even then it has a lot of noise. Most studies are based on CIF (Cost, Insurance, and Freight) and FOB (Free on Board) trade values retrieved from the IMF and/or the UN's COMTRADE databases. The IMF presents aggregate data for each country and has a wide coverage of years (1948 to present), while COMTRADE provides the value of shipping costs by commodity level. CIF is the value recorded by the importer when the shipment is received and FOB is the value recorded by the exporter when the merchandise is shipped. By constructing a CIF/FOB ratio you get the ad-valorem cost of transportation, the cost of shipping relative to the value of the good. A concern with the "matched partner" technique is that the CIF and FOB values may differ due to different reasons such as classification of the products, variations in exchange rates from the time it was shipped to the timed it arrived to the importing country, or simply differences in the value or quantities reported. In fact, Hummels and Lugovskyy (2006) found that roughly half of the observations from the IMF data lie outside 0 percent and 100 percent ad valorem cost. If the ratio is more than 2, it means that transportation cost exceeds the value of the good transported. This is possible especially with very inexpensive goods in the exporting country. However, if the ratio is less than a unity it means that transportation cost is less than zero, which is not possible. Therefore, in this matter, I will measure transport costs by measuring the quality of infrastructure and including distance and dummy variables for landlocked countries and if the countries share a border.

b. Containerization

Containers have become the most prevalent means of transport, production, and distribution within the global production network (Notteboom and Rodrigue, 2009). Transport refers to the transfer of goods from one place to another; however, production is less direct related to the container itself, it is associated with the fact that containers became a standard of production quantities as companies now produce based on containerized batches. Finally, distribution refers to the new methods of transportation based on the new container standards; in other words, a shift to time based management strategies.

Furthermore, a new concept of "intermodalism" was born. It refers to the idea of transporting the same container, with the same cargo, thru different transportation modes: ships, trucks, and trains. By reducing the number of times the product is handled to only packing into the container upon shipment from the factory and unpacking when it gets to its final destination, pilferage and damages were reduced. Improving container based vessels and ports represent large investments in infrastructure that needs to be carefully considered. Improving the infrastructure could increase trade, but it could also result in high debt if the expected gains from the port are not achieved (Talley, 2000).

With container shipping, liner companies not only reduced costs, but also as the world became more interconnected and economies of scale represented greater gains, they also gained control over ocean transportation. Vessels have increased in size and the number of different ports of call has decreased. Ships are loaded and unloaded fewer times, and containers are shipped by land to their final destination. The shipping industry is becoming more concentrated giving liner companies the ability to choose which port to use and consequently have greater power over the industry. Furthermore, if we add the constant search for increasing the size of containers and thus vessels and ports, port competition increases, putting pressure on ports to have maritime access routes, and reduce time and cost of ships calls. Ports need to have sufficient destination cargo to be competitive (Notteboom and Rodrigue, 2009; and Talley, 2000).

c. Time and distance

The empirical research done by Kano, Kano and Takechi (2013) concluded that distance creates a large price gap between the producing and consuming regions and affects the type of products sent from one region to another. The price gap comes basically from the cost of getting the product to the consumer region. Disdier and Head (2008) concluded that a 10 percent increase in distance lowers trade by 9 percent.

The costs are mainly related to transportation and communication costs; however, there is always a risk involved when moving the product. Products shipped are normally insured, nevertheless, given the evolution of the global supply chains, losing the product in transit does not only mean the loss of the cost of that product, but also the time lost by not having the input ready for the next step in the production chain (in case of intermediate goods), or not being available to sell (in the case of final goods). The global supply chain of trade has made just-in-time inventory management more time sensitive. Delays in the delivery of intermediate goods affect the entire production process and could result in the reduction of trade as producers may buy more input locally to reduce the risk. In 1992, European Union members removed internal customs posts, reducing time in transit since trucks did not have to stop at the borders any more. Hummels and Schaur (2012) estimated that each day in transit is worth between 0.6 percent and 2 percent the value of the good; thus delays lower the probability of exporting. Hence, air cargo has risen faster than ocean freight.

All these research results lead to the conclusion that better infrastructure, less time in transit, and lower transportation costs improve trade for the producing and consuming countries as well as the transit countries. Countries can foster trade expansion through a range of different strategies, such as improving infrastructure or they might choose to lower trade barriers in order to become more competitive.

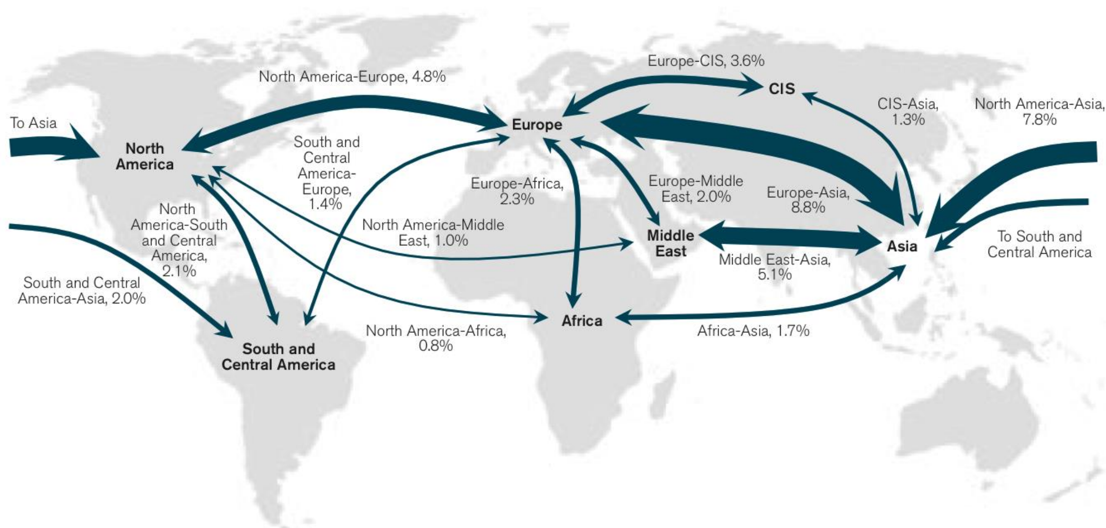
This paper looks at the effect of infrastructure on exports. It differs from previous research since it will use more recent data (2012). It will follow Nordas and Piermartini (2004) gravity model by including the infrastructure and GDP of both importer and exporter countries, landlocked dummies, common socioeconomic aspects, and tariffs rates and by running an OLS regression and a country fixed-effects regression. It differs from Limao and Venables (2001) as it will use data from COMTRADE (the UN's Commodity and

Trade Database) to measure bilateral trade volumes instead of shipping company quotes; and from Clark et al. (2004) since the transport costs will be measured as a function of distance (they computed their own transport costs in a previous regression).

3. International Trade

"Death of distance" has become a popular term to refer to today's globalization, but transportation costs still represent a large proportion of trade costs. Nevertheless in recent years trade between regions has increased substantially as countries become more interconnected. Starting with the industrial revolution and followed by constant improvement and advancements in technology, countries have been able to take advantage of the world market. Companies have expanded their market by offering their final product in many countries around the world and lowered their costs by moving their production process to countries where labor is cheaper.

Figure 1
Share of Total Trade between Geographic Regions in World Trade, 2011
(Percentages)



Source: WTO Secretariat estimates.

Note: World trade includes intra-EU trade. Arrow weights based on shares in 2011. Trade within regions and with unspecified destinations represented 54% of world trade in 2011.

Figure 1 shows the percentage of world trade among pairs of different geographical regions in 2011. The arrows represent the degree of bilateral trade between the regions: the wider the arrow the greater the percentage of trade between both regions.

Asia, Europe and North America play an important role in world trade. By 2011 the three greatest bilateral trade flows are those between Asia and Europe (8.8 percent of world trade), Asia and North America (7.8 percent of world trade) and Asia and the Middle East (5.1 percent of world trade). Bilateral trade between Asia and Europe and Asia and North America represented about 17 percent of world trade in 2011. According to studies done by ODEPAL, currently 35 percent of the world trade sails through the Pacific Ocean connecting Asia to the rest of the world. Europe represents 24 percent of the world's sea cargo while the East Coast of Canada, United States and Mexico represent 32 percent. In addition, the United States East Coast represents 26 percent of the world trade and 65 percent of the US total trade (Gomez, 2013).

Table 1
Growth in the Volume of World Merchandise Trade by Selected Region and Economy, 2005-2012

Exports			Annual percentage change	Imports		
2005-12	2011	2012		2005-12	2011	2012
3.5	5.5	2.5	World	3.5	5	2
3.5	6.5	4.5	North America	1.5	4.5	3
1.5	7	0.5	South and Central America	8.5	13	2.5
2	5.5	1	Europe	1	3	-2
3	2	1.5	Commonwealth of Independent States (CIS)	8.5	17	6.5
7	6.5	2.5	Asia	6	6.5	3.5

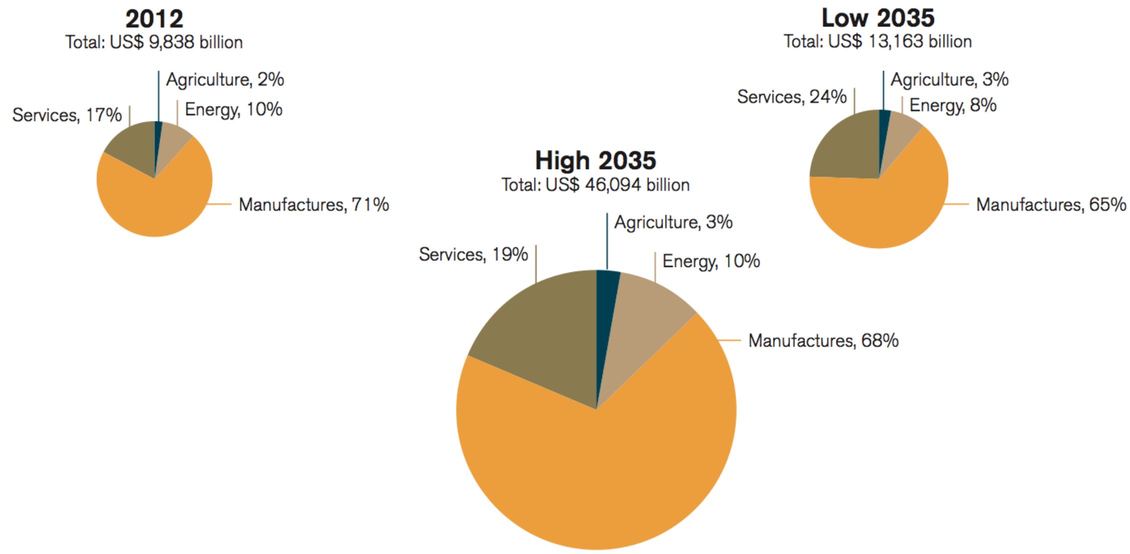
Source: www.wto.org

The trade between Asia and North America and Europe not only represents a significant portion of the world trade, but it has also been increasing annually. As seen in Table 1, between 2005 and 2012 Asia represented the largest share in the increase in exports, 7 percent, on the import side the largest increases in imports have been on the part of developing countries, primarily South and Central America (8.5 percent) and the Commonwealth of Independent States (8.5 percent). In the future the volume of world merchandise trade is expected to continue to increase overall although the share of trade of each region could vary.

Trade volumes depend not only on transportation and technology, but also on each country's GDP. The Organization for Economic Co-operation and Development (OECD) (2012) forecasted that OECD countries' share of world GDP would decline. Currently they constitute two-thirds of world GDP. This share is expected to fall to one-half by 2030 and to about 44 percent by2060. However, the OECD also predicted that besides China and India, no non-OECD country would change their share (World Trade Report, 2013, p.92). These predictions are in line with the cheap labor and increase in manufacturing in China in the recent past. Also, for the GDP it is also important to take into account the increase in population that now has entered the labor market.

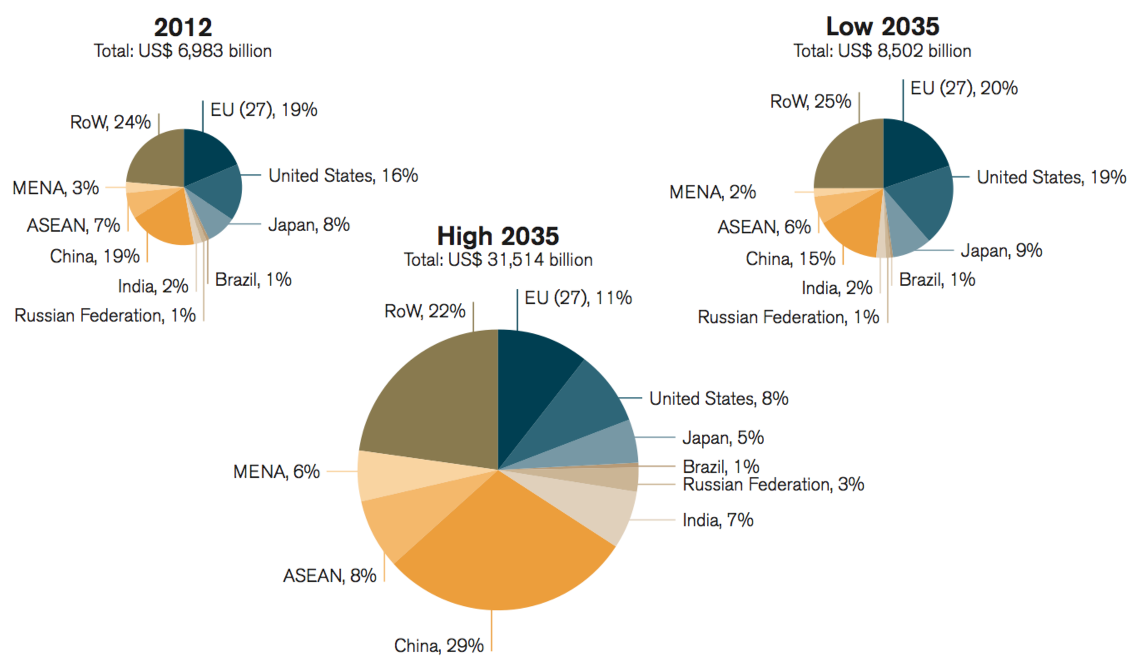
In 2007 The World Bank made long-term predictions about trade and found that "trade would continue to be more dynamic than GDP." They forecasted that exports would more than triple, while GDP would double by 2030, assuming no changes in trade policies (World Trade Report, 2013, p.93). Nonetheless, Anderson and Strutt (2012) recognized that transport and communication costs play an important role in trade and that if they continue to decline countries would further benefit from trade (World Trade Report, 2013, pp.93-94). There is no definite conclusion as how trade would evolve, but all agree in that it will increase, and the benefits will depend on trade policies, transportation and communication costs.

Figure 2
Sectoral Shares in Global Exports (Excluding Intra-Trade), Constant 2004 Prices
(Percentages)



Sources: WTO Secretariat, based on Fontagné and Fouré (2013) and Fontagné et al. (2013).

Figure 3
Country/Regional Shares in Global Exports of Manufacturers (Excluding Intra-Trade), Constant 2004 Prices
(Percentages)



Sources: WTO Secretariat, based on Fontagné and Fouré (2013) and Fontagné et al. (2013).
Note: MENA: Middle East and North Africa; RoW: Rest of the World.

Moreover, when looking at merchandise trade, it has been forecasted that developed countries will increase trade in services, while developing economies will continue with trade in manufacturing goods. Nonetheless, manufacturing will continue to represent more than half of world trade. Since developing countries have a greater focus on manufactured goods they can benefit from this trend and increase trade by attracting liner companies thru an improvement in their infrastructure.

In Figure 2 and 3 it can be seen how the share of trade of services in total trade increases and the share of manufacturing decreases, but manufacturing on both, the "high" and "low," scenarios still represents most of international trade (at least 65 percent). Further, energy trade share does not seem to change much, and agriculture represents a small share in any scenario.

4. Data

This study focuses on how the quality of infrastructure affects the exports of a country. To measure the impact this study includes variables on three different aspects of infrastructure: overall infrastructure, which includes the assessment of the quality of transport, telephony, and energy; port infrastructure, which includes the quality of ports only or ease of access to a port if the country is landlocked; and air infrastructure, which measures the quality of airports. This study includes other variables to control for each country'sindividual characteristics and partner countries' characteristics. In this section I will discuss the variables and data used for looking at infrastructure and exports.

a. Exports

Exports were chosen as the dependent variable of trade since most countries tend to focus their international trade efforts on export promotion; governments are constantly looking for ways to increase the quantity and diversity of goods being exported. Globalization provides a wider market allowing firms to find customers anyplace in the world. As a result industries tend to grow in size and achieve economies of scale reducing prices for both the international and the domestic markets. Governments provide incentives such as subsidies or the establishment of industrial parks near ports and airports in order to increase exports.

Many studies have focus on exports and imports from and to the United States (Limao and Venables, 2001; Hummels and Schaur, 2012; and Baldwin and Harrigan, 2011). In contrast, Nordas and Piermartini used several countries as trading partners with data from the UN COMTRADE database, but they focused on imports and their data is for the year 2000.

For this study, the export data used was retrieved from UN COMTRADE Database. The bilateral trade flows values are for 2012 and measured in dollars. There are 113 reporter countries (exporter) and 143 partner countries (importer) for a total of 13,203 country partner observations. Table 2 shows the summary statistics for exports.

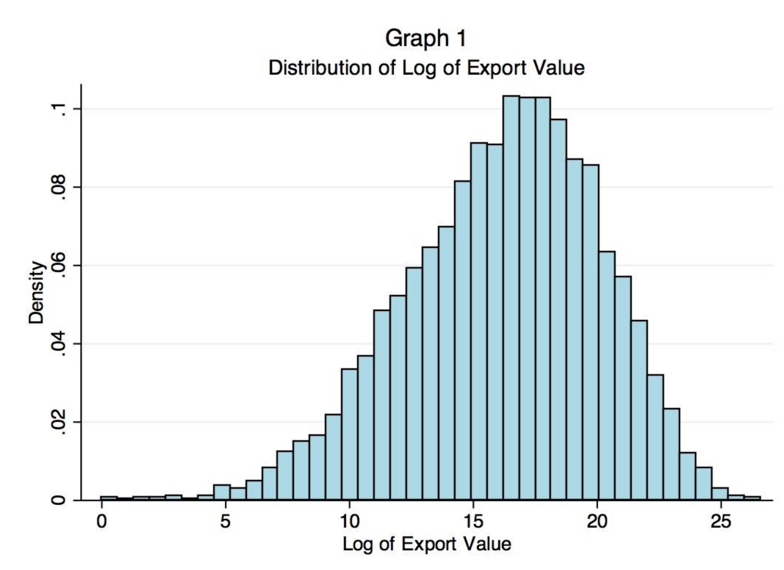
Table 2
Summary Statistics

Exports Value ($MM)		Percentile	
Mean	1,183.21	1%	0.001
Std. Dev.	8,963.06	25%	0.825
Min.	0.000001	50%	15.489
Max.	352,438.20	75%	187.01
		99%	22,216.24
N	13,203		

Exports have a mean value of $1,183 million in exports between trading partners with a minimum value of $1 and a maximum value of $352,438 million. On the right side of the table is the percentile distribution; it shows that the 50th percentile is $15.5 million in exports. Some countries that trade a large volume of merchandise like Canada and the United States, Mexico and the United States, China and Hong Kong, and China and the United

States cause the difference between the mean and the median. It is possible to notice some of these high levels of trade come from NAFTA member countries, who also share a border.

The export variable will be used in the log form in order for it to be normally distributed, in other words, to reduce the skew and therefore the influence of outliers on the results. The distribution of the Log of Exports Value is shown in Graph 1.



b. Infrastructure

As mentioned before, I will measure infrastructure in three different ways. All three indicators of quality of infrastructure come from the Global Competitiveness Index (GCI) reported by the World Economic Forum. GCI is composed of 12 pillars intended to provide insight of a country's productivity and therefore their level of prosperity; infrastructure is the second pillar that is divided into transport infrastructure and electricity and telephony infrastructure. Measurements are based on survey questions asked to representative firms of each country. The firms are chosen with the help of World Economic Forum's Partner Institutes who follow detail-sampling guidelines to choose the sample of respondents. Partner institutes include research or academic institutes, business organizations, national competitiveness councils, and in some cases survey consultancies.

The first measurement used in this study is overall infrastructure, which includes the assessment of the quality of transport, telephony, and energy. It answers the question of "how would you assess general infrastructure (e.g., transport, telephony, and energy) in your country?" The second measurement addresses port infrastructure, which includes the quality of ports only or ease of access to a port if the country is landlocked. It answers the question of "how would you assess port facilities in your country?" For this study I will only focus on countries with access to the ocean, not landlocked, to measure the effect of port quality on exports. The third measurement is air infrastructure, thus measures the quality of airports only, and answers the question of "how would you assess passenger air transport infrastructure in your country?" The fact that quality of air infrastructure measures passenger air transport does not affect the estimates since in general the infrastructure for passenger planes and cargo planes is the same. The variables take a value from 1 (extremely underdeveloped – among the worst in the world) to 7 (extensive and efficient – among the best in the world).

A fourth measurement of infrastructure will be included in the regression: irregular payments for exports and imports. It is also part of the GCI and it is the answer to the question "how common is it for firms to make undocumented extra payments or bribes connected with imports and exports in your country?" It takes a value from 1 (common) to 7 (never occurs). The reasoning for including this variable is because many times extra payments and bribes are related to inefficiency and red tape, which both have consequences on time, and time increases transport costs. Also, irregular payments can be related to illegal activities and Clark et al. (2004) argue that crime represents a threat to ports operations and the merchandise in transit.

Table 3 reports the median, minimum and maximum values of the infrastructure indicators. Port, air, and overall infrastructure are used separately in the regressions to avoid endogeneity due to simultaneity of the variables. Furthermore, I present a measure of infrastructure for 2012 and a lag variable with data from 2008 for overall and port infrastructure and data from 2009 for air infrastructure. The lag variable is intended to reduce the possibility of endogeneity and see if better infrastructure affects exports instead of large volume of exports resulting in improvements in infrastructure.

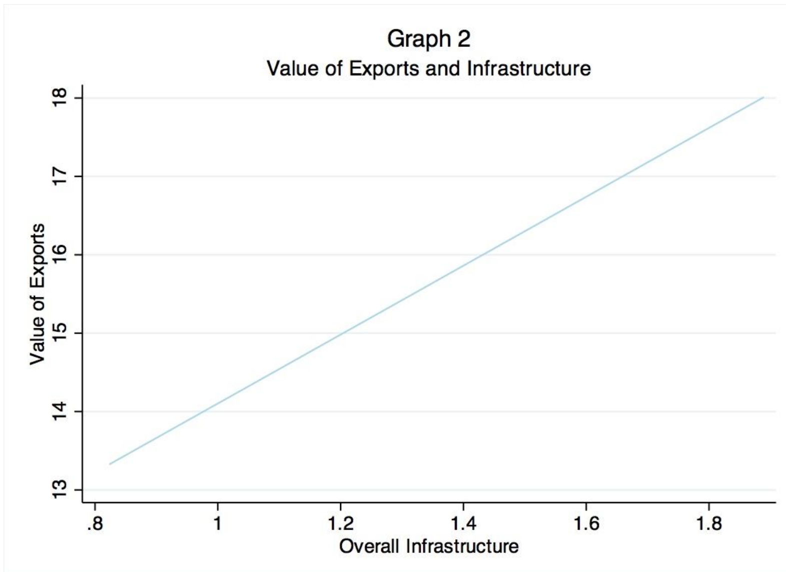
Table 3
Quality of Infrastructure

Year 2012	Median		Minimum		Maximum	
Overall Infrastructure	4.15	Russia / Gambia / Indonesia / Slovakia	1.85	Libya	6.61	Switzerland
Port Infrastructure	4.5	Thailand	2.15	Timor-Leste	6.81	Netherlands
Air Infrastructure	4.23	Rwanda / Montenegro	2.11	Lesotho	6.76	Singapore
Irregular Payments in Exports and Imports	3.61	Panama / Serbia	1.76	Yemen	6.6	New Zealand

Year 2008/2009	Median		Minimum		Maximum	
2008 Overall Infrastructure	3.54	Côte d'Ivoire / Gambia	1.57	Chad	6.71	Switzerland
2008 Port Infrastructure	4.15	Gambia / Kuwait	1.84	Haiti	6.83	Singapore
2009 Air Infrastructure	4.54	Lithuania / Montenegro	2.19	Paraguay	6.89	Singapore

Source: Global Competitiveness Index, World Economic Forum

All the infrastructure variables are expected to have a positive sign, including irregular payments (since 1 means it is common and 7 means it never occurs). For port, air, and overall infrastructure this means that better quality of infrastructure should improve efficiency and reduce transport costs, therefore increasing exports. Gaulier et al. (2008) concluded that not including infrastructure in the equation would bias the distance variable, and Limao and Venables (2001) showed that infrastructure might explain about 40 percent of transport costs for coastal countries and 60 percent for landlocked countries. Graph 2 shows the fitted values for exports given overall infrastructure. As you can see, a higher quality of infrastructure is associated with higher exports.



For irregular payments the positive sign means that as extra payments or bribes decrease, trade increases; in other words, as the variable moves from 1 to 7, extra payments and bribes take place less often and trade increases. As mentioned before, for irregular payments 1 means they are common, while 7 means they do not happen. Clark et al. (2004) found that if countries like Brazil or China (countries with organized crime around the 75th percentile) reduce their organized crime to level of countries like New Zealand or United Kingdom (with crime around the 25th percentile), they could increase their port efficiency by one point, reducing transport costs by about 6 percent.

c. *Variables to measure transport costs*

As mentioned before, data on transport costs in international trade is rarely accurate and contains a lot of noise. Most of the inaccuracy comes from the fact that the value reported by the importer differs from the value reported by the exporter; they may differ due to reasons such as classification of the products, variations in exchange rates from the time it was shipped to the timed it arrived to the importing country, or simply differences in the value or quantities reported. To avoid using the CIF/FOB ratio due to its unavailability or poor quality, I will measure transport costs with four variables: infrastructure, distance, a dummy variable for landlocked countries and a dummy variables if the partner countries share a border. This is the common way transport costs are measure in the gravity equation.

Data for distance and landlocked and border dummies were retrieved from the CEPII, a French research center in international economics. The CEPII has two datasets, one with country specific geographical variables from which the landlocked dummy was obtained, and the other is dyadic since the data corresponds to variables for a pair of countries like distance and border. The distance used for this study is kilometers from the capital cities of each pair of countries. Also, a measure for latitude was obtained from the CEPII first dataset as well, intended to capture the overall remoteness of either the exporter or importer from the rest of the markets. Table 4 shows the summary statistics for the variables used to capture transport costs.

Table 4
Measures of Transport Costs

	Mean	Std. Dev.	Minimum	Maximum
Distance (Km.)	7,016.88	4,354.12	59.62	19,812.04
Latitude (Exporters)	24.36	27.19	-44.28	64.15
Latitude (Importers)	21.82	25.72	-44.28	64.15
Border	0.03	0.16	0	1
Landlocked (Exporters)	0.17	0.38	0	1
Landlocked (Importers)	0.20	0.4	0	1
N	13,203			

The first column shows data about the distance from exporter to importer capital cities in kilometers. The mean distance from the pair of countries is 7,017 km, yet it ranges from

60 km to 19,812 km. Moreover, only 3 percent of the country partners share a border and about 20 percent of countries are landlocked.

Exports are expected to decrease if transport costs increase, so in terms of transport costs, distance and latitude are expected to be negative since the further away the two trading partners are the higher the transport costs, thus the lower the trade. In contrast, transport costs are expected to decrease with adjacency due to the ease of trading and integration between neighboring countries and thus the border dummy is expected to have a positive sign since it increases trade. Furthermore, landlocked countries have fewer alternatives for transport modes and need to go through intermediate countries in order to reach a port and ship goods by ocean. Consequently being landlocked is expected to reduce trade.

d. Other variables

The gravity model uses market size and bilateral trade barriers to explain trade. To account for market size GDP PPP (Purchasing Power Parity) has been included; also GDP PPP per capita is often used as a demand-related parameter. In a sense these two variables measure output and expenditure of goods and services. Baldwin and Harrigan (2011) found that GDP has a powerful positive effect on bilateral trade; one standard deviation increase in market size will increase the probability of exporting by 0.20. Similarly, one standard deviation increase in GDP per capita will increase the probability of exporting by 0.13. GDP measures were obtained from the World Bank's World Development Indicators for 2012.

The bilateral trade barriers are measured with transport costs, and dummy variables to account for same language, currency and colony. Anderson and Wincoop (2004) calculated a tax equivalent of trade costs for industrialized countries equivalent to 170 percent, which breaks down in 21 percent transportation costs, 44 percent border related trade barriers, and 55 percent retail and wholesale distribution. The 44 percent for border related barriers breaks down in 8 percent policy barriers, 7 percent language barrier, 14 percent currency barriers, 6 percent information costs, and 3 percent security. The language dummy measures the idea that there must be communication for trade; when translating or communicating in a foreign language some of the information could be lost or misunderstood. Thus, sharing the same language is an advantage for communication and lessens trade costs; therefore it should have a positive effect on trade.

Producers are more likely to ship their product to consumers with whom they can communicate and relate. The latter introduces the colony variable, which controls for countries that were part of the same colony at some point. Countries that have ever been part of the same colony can relate better to each other, they might share common customs, similar laws and do business in similar ways. Thus, following the same reasoning as for language, colony should also have a positive effect on trade.

Currency, on the other hand, seems not to have a specific reason of why it affects trade; some possible explanations are the non-existing risk of exchange rate changes if counties use the same currency, government commitment resulting in an incentive for the private sector to trade, or greater financial integration (Rose, 2000). Nevertheless, it has shown a positive impact on trade. Language, currency and colony variables were obtained from the CEPII dyadic dataset.

A last variable, tariffs, will be implemented as a trade barrier or cost. Tariffs will be measured as the trade-weighted average tariff rate for the partner (importer) country. Tariffs have been decreasing over the last 60 years, as international trade becomes a more common practice and trade negotiations take place; moreover, countries have formed Free Trade Agreements (FTAs) reducing barriers for member countries. Nordas and Piermartini (2004) found that a 10 percent reduction of tariffs increases trade by about 12.5 percent. A measure of tariffs is not often included in the gravity equation; however, they argue that there is a high degree of variability in cross-country bilateral applied tariffs and that not including it in the regression could result in omitted variable bias. Table 5 shows the summary statistics for the importer's tariffs rates.

Table 5
Tariffs

	Median		Minimum		Maximum	
Tariff Rates	5.69%	Yemen	0.35%	Singapore	27.06%	Iran

Source: Global Competitiveness Index, World Economic Forum

Tariffs are expected to decrease trade, since exporters will look for markets where their products are more competitive. There should be caution when interpreting this variable since non-tariff barriers also play a role in trade and are not measured in this dataset. For example, some countries with low tariffs might have a policy where they implement quotas instead. The next table has a summary of all the variables with a short description and the source.

Table 6
Summary of variables

Variable	Description	Source
Exports	Dollar value of exports for 2012.	UN COMTRADE
GDP	GDP PPP (Purchasing Power Parity) for 2012 in billions dollars.	World Bank's World Development Indicators
GDP per Capita	GDP PPP, per capita (Purchasing Power Parity) for 2012.	World Bank's World Development Indicators
Tariffs	Trade-weighted average tariff rate for the partner (importer) country	World Economic Forum's Global Competitiveness Index
Overall Infrastructure	Assessment of the quality of transport, telephony, and energy. Takes a value from 1 (extremely underdeveloped) to 7 (extensive and efficient).	World Economic Forum's Global Competitiveness Index
Port Infrastructure	Quality of ports or ease of access to a port if the country is landlocked. Takes a value from 1 (extremely underdeveloped) to 7 (extensive and efficient).	World Economic Forum's Global Competitiveness Index
Air Infrastructure	Quality of airports. Takes a value from 1 (extremely underdeveloped) to 7 (extensive and efficient).	World Economic Forum's Global Competitiveness Index
Irregular Payments	Measure of how common is for firms to make undocumented extra payments or bribes connected with imports and export. Takes a value from 1 (common) to 7 (never occurs).	World Economic Forum's Global Competitiveness Index

Variable	Description	Source
Latitude	Degrees to measure the remoteness of a country based on north or south from the equator.	CEPII
Border	Dummy variable = 1 if the countries share a border, 0 otherwise.	CEPII
Language	Dummy variable = 1 if the countries have the same language, 0 otherwise.	CEPII
Currency	Dummy variable = 1 if the countries have the same currency, 0 otherwise.	CEPII
Colony	Dummy variable = 1 if the countries were ever part of the same colony, 0 otherwise.	CEPII
Landlocked	Dummy variable = 1 if the country is landlocked, 0 otherwise.	CEPII

Note: Some variables are used in the log form; the text will indicate the form the variable is used. There are 113 reporter countries (exporters) and 143 partner countries (importers).

5. Methodology

The gravity equation is the standard analytical framework for the prediction of trade. Its use in international trade started in the early 1960s and changes to improve it were developed later (Limao and Venables, 2001). The most common gravity equation takes the following form:

$$x_{ij} = \beta_1 y_i + \beta_2 y_j + \sum_{n=1}^{N} \beta_n z_{ij}^n + \varepsilon_{ij}$$

where x_{ij} is the log of exports from country i to country j, y_i and y_j are the log of GDP of both countries, z_{ij}^n are all observable variables that impose a bilateral trade barrier, and ε_{ij} is the error term.

The gravity model allows inference about unobservable trade costs by linking trade costs to observable cost proxies and making an assumption about error terms which link observable trade flows to predicted values (Anderson and Wincoop, 2004). The common observable variables used include infrastructure, distance, adjacency, common language, common colony, and differentiating landlocked and island countries. The error term is assumed to be normally distributed and independent of the explanatory variables. It is important to keep in mind that bilateral trade flow measurement errors are common especially since the exporter and the importer data often do not match. Therefore no "matching partner" technique is being used. Correlation of the error term with the explanatory variables may come from omitted variable bias and endogeneity.

Anderson and Wincoop (2004) raise a common concern about currency unions causing endogeneity. The main argument is since there is no clear reason why currency unions increase trade, the case might be that instead of countries increasing trade because they started using the same currency, they join a currency union because they have close trade relationships in the first place. Rose (2000) suggests that there is no endogeneity and that trade does not play a major role when becoming part of a union. He went further and used instruments associated with inflation and concluded that currency unions do have an effect on trade.

For this study I will estimate three equations. The first equation will use the basic variables to measure transport costs, information costs and other bilateral trade barriers. I will use the lag variable for infrastructure to address endogeneity. The estimated equation for overall and air infrastructure is the following:

$$log\, x_{ij} = \beta_0 + \beta_1\, log\, GDP_i + \beta_2\, log\, GDP_j + \beta_3\, log\, Dist_{ij} + \beta_4 Border_{ij} + \beta_5 Lang_{ij} + \beta_6 Colony_{ij} + \beta_7 Landlocked_i + \beta_8 Landlocked_j + \beta_9 log\, LagInfra_i + \beta_{10} log\, LagInfra_j$$

where x_{ij} are the exports from country i to country j, GDP_i and GDP_j are the log of GDP PPP of both countries respectively, $Dist_{ij}$ is the distance in kms from the capital cities of country i and country j, $Border$, $Lang$, and $Colony$ are dummy variables equal to 1 if the countries share border, language or were ever part of the same colony respectively and zero otherwise, $Landlocked_i$ and $Landlocked_j$ are dummy variables equal to 1 if country i or $j$are a landlocked country, $LagInfra_i$ and $LagInfra_j$ are the measures of overall and air infrastructure that will be added one at a time in the regression. For port infrastructure, the regression will be the same but without the landlocked variables since I will be only looking at countries with access to the ocean, not landlocked.

$$log\, x_{ij} = \beta_0 + \beta_1\, log\, GDP_i + \beta_2\, log\, GDP_j + \beta_3\, log\, Dist_{ij} + \beta_4 Border_{ij} + \beta_5 Lang_{ij} + \beta_6 Colony_{ij} + \beta_7 log\, LagInfra_i + \beta_8 log\, LagInfra_j$$

A second regression is estimated using four more variables that the literature has used to account for bilateral trade costs. They are irregular payments ($IrrPay_i, IrrPay_j$) to account for extra expenses due to crime and bribes; a dummy variable for currency ($Currency_{ij}$) equal to 1 if countries have the same currency, and zero otherwise to acknowledge the effect of being on a currency union assuming there is no endogeneity based on Rose (2000); latitude (Lat_i, Lat_j) to measure the remoteness of the exporter and importer country respectively, how far are they from the rest of the markets; and tariffs (T_j) imposed by the importing countries. The second regression is as follows (excluding the landlocked variables for port infrastructure):

$$\log x_{ij} = \beta_0 + \beta_1 \log GDP_i + \beta_2 \log GDP_j + \beta_3 \log Dist_{ij} + \beta_4 Border_{ij} + \beta_5 Lang_{ij} + \beta_6 Colony_{ij} + \beta_7 Currency_{ij} + \beta_8 Landlocked_i + \beta_9 Landlocked_j + \beta_{10} \log IrrPay_i + \beta_{11} logIrrPay_j + \beta_{13} log\, Lat_i + \beta_{14} log\, Lat_j + \beta_{15} T_j + \beta_{16} log\, LagInfra_i + \beta_{17} log\, LagInfra_j$$

Another method to measure the effects of bilateral trade barriers on trade is to use country specific fixed effects instead of multilateral resistance indices. Hence, for a third equation I estimated a gravity model using the country fixed effects clustered by trading partner pair. Following Nordas and Piermartini (2004) I also generated the infrastructure variables used to further explore the effect infrastructure has on trade. One variable measures the effect of low transport costs on trade given that better infrastructure lowers transport costs; and the second variable measures the effect on trade of the use of similar transport systems and technology from both countries. The third equation is as follows:

$$\log x_{ij} = \beta_0 + \beta_1 \log Dist_{ij} + \beta_2 Border_{ij} + \beta_3 Lang_{ij} + \beta_4 Colony_{ij} + \beta_5 Landlocked_i + \beta_6 Landlocked_j + \beta_7 avgInfra_{ij} + \beta_8 goodInfra_{ij} + \beta_{9i} \sum D_i + \beta_{10j} \sum D_j$$

where $avgInfra_{ij}$ is a dummy that takes the value of one if the average of the quality of infrastructure for both countries is greater than the average value for all partner countries and zero otherwise; $goodInfra_{ij}$ is a dummy that takes the value of one if both countries' individual quality of infrastructure is above the average of all countries infrastructure and zero otherwise. D_i and D_j are the fixed effect for the exporting and importing country.

6. Results

In this section I will present the results from the three equations: one with the basic control variables, a second one adding control variables for irregular payments, currency, remoteness, and tariffs, and the third one using fixed effects. For each specification of the gravity equation I did three regressions, one for each measure of infrastructure: overall, port, and air infrastructure. When looking at the effects of port infrastructure on exports, there are fewer observations since I am only looking at partner countries where none of them is landlocked. As mentioned before, the data used is cross-country for 2012 except for the lag variables of infrastructure, which are 2008 for overall and port infrastructure, and 2009 for air infrastructure.

Table 7 presents the results for the three regressions of the first specification. The overall fit of the model is good and stable between the three regressions with an R-squared ranging from 0.67 to 0.70; in other words, the explanatory variables explain at least 67 percent of the variations in the value of exports. Before looking at infrastructure, in general, all the control variables have the expected sign and are align with the results from previous studies; the elasticity of distance usually ranges between -0.7 and -1.5 and there is usually a unitary elasticity with respect to the importer country's GDP (Bacchetta et al, n.d.).

Table 7

Estimating the Effect of Infrastructure on Exports

	Overall Infrastructure		Port Infrastructure		Airport Infrastructure	
Dependent Variable: Log of Exports						
GDP Exporter	1.329***	(.012)	1.334***	(.013)	1.366***	(012)
GDP Importer	.922***	(.011)	.925***	(.012)	.917***	(.011)
Distance	-1.357***	(.023)	-1.268***	(.027)	-1.382***	(.024)
Border	1.434***	(.128)	.897***	(.146)	1.364***	(.126)
Language	.675***	(.060)	.725***	(.070)	.616***	(.060)
Colony	.559***	(.118)	.659***	(.120)	.680***	(.119)
Exporter Landlocked	-.453***	(.062)	______		-.260***	(.062)
Importer Landlocked	-.817***	(.055)	______		-.685***	(.057)
2008 Overall Infra. Exporter	1.782***	(.059)	______		______	
2008 Overall Infra. Importer	1.104***	(.059)	______		______	
2008 Port Infra. Exporter	______		1.817***	(.078)	______	
2008 Port Infra. Importer	______		1.272***	(.073)	______	
2009 Airport Infra. Exporter	______		______		1.935***	(.097)
2009 Airport Infra. Importer	______		______		1.502***	(.089)
Intercept	12.506***	(.244)	11.293***	(.291)	11.023***	(.302)
Observations	13,203		8,710		13,203	
R-squared	0.677		0.703		0.665	

Note: Robust Standard Errors in parenthesis

*** = significant at 1 percent; ** = significant at 5 percent; * = significant at 10 percent

The first column in Table 7 shows the results for overall infrastructure, which includes a measure of transport, telephony, and energy. The exporter's quality of infrastructure seems to have the largest impact on exports with an elasticity of 1.78, so a 10 percent improvement in the quality of infrastructure in the exporter country increases trade by about 18 percent. The impact due to the quality of the importer's infrastructure is somewhat smaller nonetheless it is still significant. In this case, the lag variable for infrastructure has elasticity of 1.10; meaning that a 10 percent improvement, increases exports by about 11 percent.

Columns 2 and 3 look at the port and airport infrastructure respectively. For ports, the quality of infrastructure has a greater effect on exports than in overall infrastructure with elasticity of 1.82 for the exporting country and 1.27 for the importing country. Also, the second regression increases the impact of GDP, language and colony variables while it is less affected by distance and border. Further, controlling for port infrastructure increases the explanatory power of the model with an R-squared of 0.70 even when the sample size is smaller after dropping the observations for landlocked countries. For airport infrastructure, a 10 percent improvement in the quality of the exporter's infrastructure increases exports by about 19 percent and the impact of the same 10 percent improvement in the quality of the importer's infrastructure increases exports by about 15 percent, both of them are greater than that of the impact from overall and port infrastructure.

I now include variables to control for using the same currency, the level of irregular payments or bribes, remoteness, and tariffs. Results are presented in Table 8. With this specification there are fewer observations because of missing values in import tariffs, 8,713 for overall and airport infrastructure and 6,017 for port infrastructure. The overall fit of the model is in line with the previous specification and stable between the three regressions with an R-squared ranging from 0.70 to 0.72; in other words, the explanatory variables explain at least 70 percent of the variations in the value of exports. With the exception of irregular payments in the importing country, the control variables have the expected sign and are consistent with the results from previous studies. The elasticity with respect to the importer's GDP is 0.92, and with respect to distance about -1.5. Dummy variables for border, language, colony and currency increase trade, while control variables for distance, remoteness and tariffs reduce trade. Irregular payments in the importing country, as mentioned before, is the exception with a negative coefficient in the regression for overall and port infrastructure; as the variable moves from 1 to 7, extra payments take place less often and trade was expected to rise. On the other hand, for airport infrastructure irregular payments does have a positive elasticity of 0.18, however is significant only at a 10 percent significance level. Furthermore, tariffs do reduce trade but its magnitude is small, a 10 percent increase in tariffs reduces trade by only about 0.5 percent. These results can be affected by free trade agreements that reduce tariffs for member countries.

Comparing Table 7 and Table 8 in general, the second specification appears to have a smaller impact on exports when improving the quality of infrastructure. For overall infrastructure, the elasticity of the exporter's infrastructure with respect to exports becomes 1.34 or 0.44 less than the first specification, and the elasticity of the importer's infrastructure 1.08, which is only 0.03 less than the first specification.

Controlling for port infrastructure in this specification also increases the explanatory power of the model with an R-squared of 0.72 even when the sample size is smaller after dropping the observations for landlocked countries. The measures of port infrastructure for the exporter and importer countries have elasticity of 1.18 and 1.43 respectively. In the case of airport infrastructure the elasticity is 0.87 and 1.07 respectively. It is interesting to notice that for the second specification, when looking at port or airport infrastructure only, the effect of the infrastructure in the importing country is greater than that of the exporting country.

Table 8

Estimating the Effect of Infrastructure on Exports Adding Control Variables

	Overall Infrastructure		Port Infrastructure		Airport Infrastructure	
Dependent Variable: Log of Exports						
GDP Exporter	1.295***	(.015)	1.324***	(.016)	1.326***	(.015)
GDP Importer	.919***	(.014)	.928***	(.015)	.928***	(.014)
Distance	-1.453***	(.032)	-1.536***	(.035)	-1.457***	(.032)
Border	.625***	(.136)	.304**	(.156)	.589***	(.134)
Language	.782***	(.079)	.628***	(.089)	.768***	(.079)
Colony	.394***	(.129)	.622***	(.127)	.444***	(.129)
Currency	1.185***	(.207)	.962***	(.274)	1.188***	(.203)
Exporter Landlocked	-.206***	(.068)	______		-.106	(.069)
Importer Landlocked	-.675***	(.067)	______		-.611***	(.068)
Irregular Payments Exp.	1.061***	(.134)	1.301***	(.132)	1.736***	(.111)
Irregular Payments Imp.	-.259**	(.130)	-.308**	(.130)	.181*	(.107)
Latitude Exporter	-.083***	(.033)	-.316***	(.035)	-.083**	(.033)
Latitude Importer	-.156***	(.028)	-.279***	(.035)	-.150***	(.028)
Importer Tariffs	-.058***	(.006)	-.049***	(.007)	-.046***	(.006)
2008 Overall Infra. Exporter	1.341***	(.114)	______		______	
2008 Overall Infra. Importer	1.075***	(.107)	______		______	
2008 Port Infra. Exporter	______		1.177***	(.134)	______	
2008 Port Infra. Importer	______		1.434***	(.120)	______	
2009 Airport Infra. Exporter	______		______		.865***	(.156)
2009 Airport Infra. Importer	______		______		1.071***	(.134)
Intercept	13.988***	(.378)	14.964***	(.441)	12.412***	(.422)
Observations	8,713		6,017		8,713	
R-squared	0.701		0.723		0.695	

Note: Robust Standard Errors in parenthesis

*** = significant at 1 percent; ** = significant at 5 percent; * = significant at 10 percent

The six regressions from Table 7 and 8 show that infrastructure has a positive effect on exports. I am using values of infrastructure for 2008 and 2009 to address possible endogeneity since a positive value cannot mean that exports caused a past improvement in infrastructure.

Lastly, I ran the third specification with the country fixed effects and the variables of infrastructure to measures the effect of low transport costs on trade given that better infrastructure lowers transport costs and the effect on trade of the use of similar transport systems and technology from both countries. Table 9 shows the results.

Table 9

Estimating the Effect of Infrastructure on Exports with Country Fixed Effects

	Overall Infrastructure		Port Infrastructure		Airport Infrastructure	
Dependent Variable: Log of Exports						
Distance	-1.671***	(.029)	-1.681***	(.033)	-1.663***	(.029)
Border	.859***	(.143)	.245	(.167)	.851***	(.143)
Language	.848***	(.062)	.786***	(.072)	.850***	(.062)
Colony	.682***	(.123)	.780***	(.130)	.695***	(.123)
Exporter Landlocked	-1.193***	(.437)	______		-1.260***	(.438)
Importer Landlocked	-2.141***	(.385)	______		-2.171***	(.387)
Partner Countries Avg. Overall Infra.	.211***	(.078)	______		______	
Good Overall Infra.	.033	(.084)	______		______	
Partner Countries Avg. Port Infra.	______		-.111*	(.064)	______	
Good Port Infra.	______		.072	(.074)	______	
Partner Countries Avg. Air Infra.	______		______		-.046	(.058)
Good Air Infra.	______		______		.041	(.067)
Intercept	22.283***	(.394)	22.311***	(.439)	22.342***	(.395)
Observations	13,203		8,710		13,203	
R-squared	0.773		0.795		0.773	

Note: Robust Standard Errors in parenthesis

*** = significant at 1 percent; ** = significant at 5 percent; * = significant at 10 percent

The specification has a good overall fit with an R-squared ranging between 0.77 and 0.80. The distance variable has a negative sign with an elasticity of 1.7 for the three regressions, the dummies for border, language, and colony all have a positive sign as expected, since they enhance trade, and the landlocked dummies have a negative sign, however, the magnitude of the effect of being landlocked is much greater when controlling for country's fixed effects. The elasticity being landlocked with respect to exports is -0.7 for the exporting country and -0.88 for the importing country.

Now, looking at the infrastructure variables, the first column has the measure for overall infrastructure and shows that if the average of both countries infrastructure is greater than the total average, a 10 percent improvement results in a 2.35 percent increase in exports. However, for port infrastructure the measurement is negative, indicating a decrease of 1.05 percent in exports with a 10 percent improvement. The reason for the difference in sign could be that countries with combined average of infrastructure greater than the total use other methods of transportation more often and have greater access to telephony and energy, which are included in the overall measure of infrastructure.

7. Conclusion

This study focused on how the quality of infrastructure affects the exports of a country using the gravity model. To measure the impact I included variables on three different aspects of infrastructure: overall infrastructure, which includes the assessment of the quality of transport, telephony, and energy; port infrastructure, which includes the quality of ports only; and air infrastructure, which measures the quality of airports. In addition, the study includes other variables to control for each country's individual characteristics and partner countries' characteristics. Exports were chosen as the dependent variable of trade since most countries tend to focus their international trade efforts on export promotion.

The argument for improving infrastructure can be seen from two perspectives; the first one is that reducing transportation costs would reduce the gap between the price in the producer region and the consuming region resulting in a wider range of products available to trade internationally. The amount and quality of transport infrastructure in the producing, consuming and transit countries have a major impact on transportation costs. The second one concerns future expectations of trade, when looking at merchandise trade, it has been forecasted that developed countries will increase trade of services, while developing economies will continue with trade in manufacturing goods, still manufacturing will continue to represent more than half of world trade.

The study shows that infrastructure does affects the value of exports, especially for the exporting county with elasticity for overall infrastructure between 1.34 and 1.78, 1.18 and 1.82 for port infrastructure, and 0.87 and 1.94 for airport infrastructure. Nevertheless, the importers country's infrastructure also does have a significant effect on the exports with elasticity ranging from 1.08 to 1.10 for overall infrastructure, 1.27 and 1.43 for port infrastructure, and 1.08 and 1.50 for airport infrastructure. In addition, the results show that even with technological advances, distance still represents a high cost of trade due to time of travel and uncertainties.

These findings have policy implications especially for least developed countries that tend to trade merchandise goods. Improvements in infrastructure may increase their share in world trade by becoming more attractive for importing countries to trade with and transport companies to use as a hub. However, improvements in infrastructure are expensive so governments should consider optimal combinations of public and private investment. Implementing industrial areas around ports and airports for ease of access and storage of the product could be a good start. However, there are some limitations of this study. Data on quality of infrastructure comes from survey questions carried by the World

Economic Forum; answers to these questions are subject to the respondents experience and not to tangible facts. Also, further specifications, besides using a lag variable, should be carried out to address the possibility of endogeneity between infrastructure and exports, since there is still a possibility of endogeneity after using lagged values of infrastructure.

To address the endogeneity problem a solution could be to use an instrumental variable, a good instrumental variable must be exclusionary and relevant; in other words, it has to be uncorrelated with the error term in the regression but highly correlated with the variable of interest. In this study, the instrumental variable would have to be uncorrelated with exports and highly correlated with infrastructure. The stronger the association of the instrumental variable and the variable of interest the stronger the identification of the model, resulting in better estimates. Some possible variables that could be used are data on aid provided by organizations like the World Bank and the Inter-American Development Bank, or data on armed conflicts that could have resulted in improvements or destruction of infrastructure; however, the latter could have also caused increase in exports so there must be caution when choosing the instrumental variable.

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