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Infrastructure and Agricultural Trade in North and Latin America

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Abstract

This research investigated the impact of hard infrastructure on food and agricultural trade among North and Latin American countries. We employed a modified gravity model of trade for food and agricultural imports to measure the potential impact of the quality of hard infrastructure on the prevalence and patterns of agricultural trade. Results suggest that the development of hard infrastructure by investing in new projects or renewing existing network systems can increase agricultural trade volume and enhance trade performance among North and Latin American countries.

Key words: international trade, agriculture, infrastructure

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Introduction

Continued emphasis has been placed on trade barriers that restrict bilateral trade of food and agricultural products by both developed and developing countries. Although some countries have shown substantial growth in food and agricultural trade over the past 20 years, large portions of the developing world are still behind, often from either bilateral tariff or non-tariff barriers that impedes international trade. Lee and Swagel (1995) evaluated trade flows and trade barriers across countries and argue that import competition by weak industries and poor countries are threatened more by tariff and nontariff measures in addition to other trade costs, as compared to rich countries. Trade barriers include policy measures, trade facilitation and geographic factors, information and time costs, transport costs, and other transaction costs (Anderson and van Wincoop, 2004; Hummels, 2007). Trade policy measures, such as applied tariffs, have been reduced or eliminated over the last 20 years for agricultural products (Anderson, 2004). For example, in 2000, the United States imposed a 25.91% tariff on food imported from Brazil. This rate was effectively reduced to 9.37% in 2018 (World Bank, 2018). However, given the noticeable reduction in tariff rates, the volume of agricultural trade is still relatively low in some low-income countries. For example, in 2000, Brazil imported $20.79 million of food products from Mexico at 18.97% applied tariff rate; however, the imports of food products by Brazil from Mexico was 51.46 million in 2018, given a tariff rate decline to 7.38% (World Bank, 2018). This low level of bilateral trade may be explained by other non-tariff measures such as transportation and shipment costs. Transport costs can influence food product trade, and it can affect the access to central and international markets, thereby restricting trade flows (Bougheas, Demetriades, and Morgenroth, 1999; Limao and Venables, 2001; Clark, Dollare, and Micco, 2004; Behar and Venables, 2010). Transport costs can be determined by transaction and shipment costs, quality of infrastructure, and geographic variables, such as distance, common border, and whether a country is an island or landlocked. Infrastructure, geographic factors, and distance between countries are important in determining transport costs and trade patterns, as they implicitly represent shipment and travel costs (Limao and Venables, 2001; Behar and Venables, 2010). One potential geographic disadvantage for a country is if its geographic location increases the transport costs to move goods within or across the borders of countries. Many agricultural commodities are assumed to be bulky and perishable, which may increase transportation and freight costs. Given that infrastructure and distance are two determinants of transport costs, this study investigated how changes in the quality of hard infrastructure affect trade flows of food and agricultural products, while accounting for the distance across trading countries in North and Latin America.

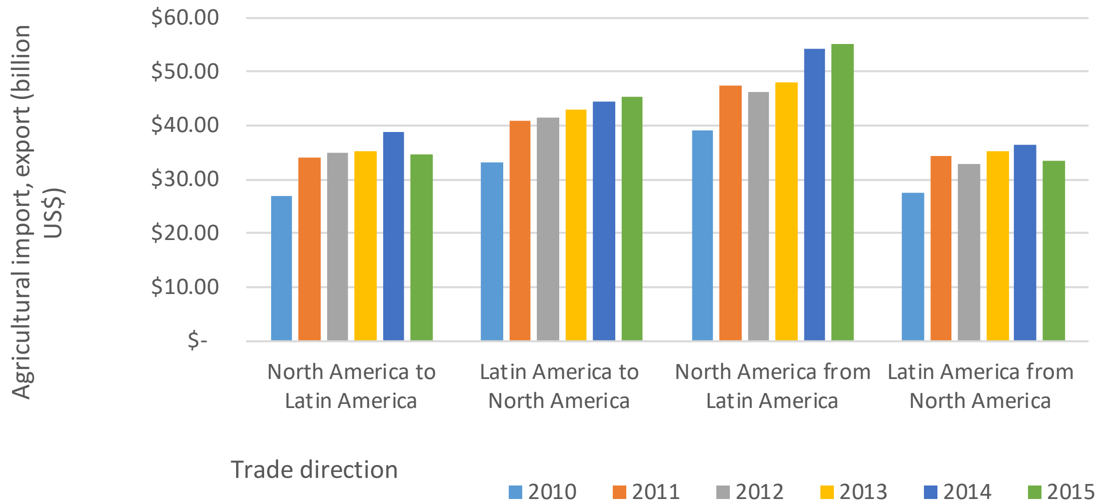
This manuscript focuses on hard infrastructure, which comprises all types of physical networks, such as roads, railroads, ports, and airports, the hard network system that enables physical connections within countries and across international borders. Physical infrastructure has a salient role in determining the cost of transportation that producers incur to move goods to local or international markets**;** thus, improving the quality of physical networks across the country and at the border may be one effective strategy to overcome distance and other geographic disadvantages and decrease transport costs. Therefore, the main objective of this study was to estimate the effect of the quality of hard infrastructure on agricultural bilateral trade volumes given other factors influencing the quantity traded, such as different tariff rates imposed by importing countries, distance and contiguity between trade partners, and differing income levels of each country. Also, the study investigated the unique contribution of each mode of transport infrastructure, including roads, railroads, ports, and airports on agricultural trade volume. A modified gravity model of trade was used to address the impact of infrastructure quality on bilateral trade among selected North and Latin American countries[1] for a 9-year period, 2006-2014. Where zero trade flows have been omitted by many past studies, this research accounts for zero trade flows in the analysis using the Poisson Pseudo Maximum Likelihood estimation method.

Agricultural Trade in North and Latin America

The United States, Canada, Argentina, and Brazil are key exporters and importers of food and agricultural products. The main forces that influence agricultural trade, in general, are changes in global food supply and demand, changes in agricultural commodity prices, countries' specific government regulations to protect agricultural trade, and direct or indirect domestic support to enhance domestic agricultural production (U.S. Department of Agriculture, 2017). The demand for food products derived by the increase in global population and income growth resulted in the increase of U.S. food export volume by more than $30 billion from 1991 to 2015 (World Bank, 2017).

Agricultural trade among North American and Latin American countries from 2010-2015 are compared in Figure 1. The total agricultural import value for North America from Latin America increased substantially from 2010 to 2015. Meanwhile, the total export levels for North America from Latin America and the imports of Latin America from North America fluctuated over the six years with a decline of roughly $3 billion from 2014 to 2015.

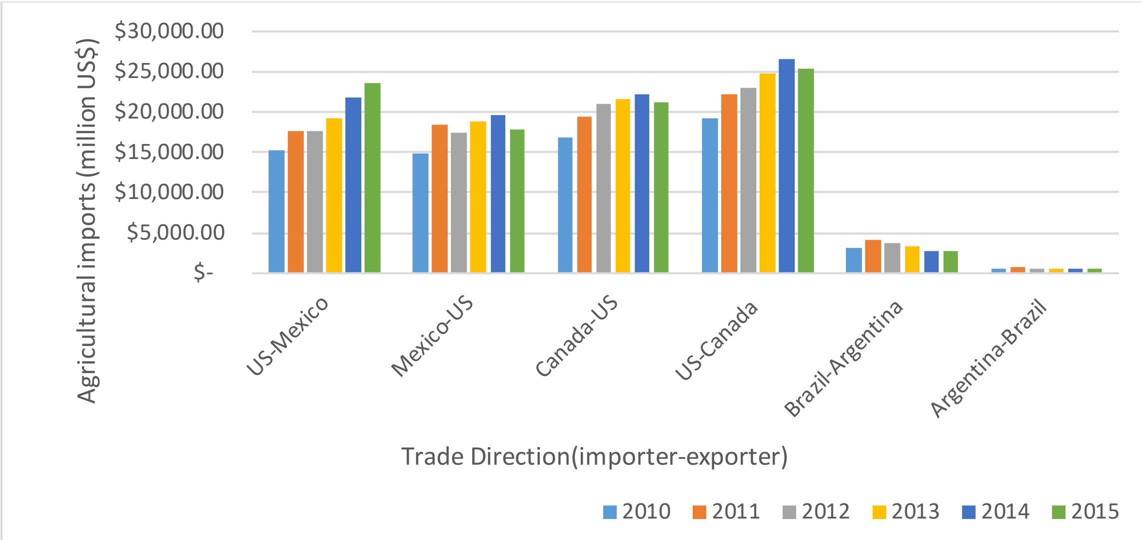
[1]North America includes the United States, Canada, and Mexico. The Latin America region includes South America (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, and Venezuela), Central America (Belize, Costa Rica, El Salvador, Guatemala, Nicaragua, and Panama), and the Caribbean (Antigua and Barbuda, Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines, and Trinidad and Tobago).



Data Source: World Integrated Trade Solution (World Bank, 2017), 2010-2015

Figure 1: Agricultural Trade Pattterns in North and Latin America 2010-2015

Agricultural trade patterns of selected countries from North and Latin America are represented in Figure 2. Countries are presented to show the difference in agricultural trade levels between developed and developing countries. The level of agricultural imports to the United States from Canada is the highest in volume as it gradually increased from about 19 trillion U.S. dollars in 2010 to 26 trillion U.S. dollars in 2014. Compared to Canada and the United States, Argentina's imports from Brazil are relatively low even though they share a common border and are members of the same regional trade agreement. In contrast, agricultural trade between Mexico and the United States increased during the period from 2010 to 2015. The volume of agricultural imports to the United States from Mexico was more than 20 billion U.S. dollars in 2015 compared to 15 billion in 2010. Thus, the difference in agricultural trade among regions or countries can be attributed to the different factors that determine the direction and volume of trade, which include tariff and non-tariff measures.



Source: World Integrated Trade Solution (World Bank, 2017), 2010-2015.

Figure 2. Total Agricultural Imports, 2010-2015

Quality of Physical Infrastructure

Infrastructure variables have been represented by a weighted average quality index in the gravity model of trade to reflect the level of infrastructure quality in a country. The indices are valued from 1 to 7, where 1 represents the lowest quality, and 7 is the highest quality, using country data provided by the Global Competitiveness Reports 2006-2014 (Schwab, 2014). In general, for ground networks, the lowest quality hard infrastructure, with index values of 1, refers to routes which are normally without any construction and maintenance and are unpaved or gravel roads and railroads with bad conditions. Low-quality ground networks are common in most developing countries and oftentimes in rural areas of developed nations. For ports, low-quality ports are assumed to be small in size with old and degraded facilities and institutions and small-sized vessels. They have higher turnaround times for ships, ship to nearby countries, and serve a relatively low number of customers around the world. High-quality hard infrastructure, with index values of 7, comprises paved and smooth roads that connect cities and rural areas in the country with no vehicle congestion or traffic. High-quality ports can support large vessels that can carry large, heavy-weight cargo and are located in an accessible coastal border of a country. They have good and new storage facilities, minimal congestion, and they provide quicker services to customers with less costs to all parties. They also provide easier access to railroads, roads, and highways to move cargo on the interstates or to inland cities. Brazil is an example of an important agricultural exporter and importer with low to medium overall hard infrastructure quality, with a weighted average quality index value of 3.9 in 2014. On the other hand, the United States is an example of a highly developed country with good overall hard infrastructure, with a weighted average quality index value of 5.7 in 2014.

Literature Review

Cross-country variation in transport costs can largely impact the trade volumes. Transport costs include the cost of handling and shipping containers, insurance charges, inventories, and other fees related to finishing paper work and delay of shipment across borders (Anderson and van Wincoop, 2004). However, it is not easy to quantify the value of transport costs, especially for the opportunity costs associated with shipment delay. Kurmanalieva (2006) employed transport density to measure transport costs by using the minimum distance between two countries as an approximation for the transport density, as the shortest travel path is assumed to be used more by traders. Limao and Venables (2001) used three different ways to measure transport cost values, including shipping costs data, CIF/FOB ratio,[2] and gravity model of trade. They utilized data for 103 economies to assess the influence of infrastructure and transport costs on bilateral trade. Findings indicated that being a landlocked country increases shipping and transport expenses by about 55% higher than a coastal country, at the median. The authors included own country infrastructure, partner, and transit country infrastructure with other geographic factors to analyze the impact of transport costs on trade volume. Conclusions indicate that own country infrastructure, partner infrastructure, and transit country infrastructure significantly affect trade volume with an elasticity of 1.32, 1.11, and 0.60, respectively. On the other hand, Behar and Venables (2010) address how a change in transport costs might impact international trade and what might be the determinants of the transport costs. The authors suggest that transport costs are determined by a set of variables, including distance and geography of a country, quality of infrastructure, trade facilitation, freight and fuel costs, and transport technology.

Hummels (2007) investigated why world trade of all goods has increased by more than 3,000 million tons (about $9 million) from 1980 to 2004. Hummels (2007) argues that one important possible reason for the increase in international trade volume is the reduction in transport costs and development in transportation and physical infrastructure. The author suggested that the importance of transport costs can be evaluated relative to the value of trade, relative to other trade barriers (i.e., tariff), or relative to change in prices of goods. Dillon and Barrett (2016) provide empirical evidence for the role of infrastructure and transportation costs in determining local market conditions, including internal and external exchange of the products. The authors explored price transmission from global market to local markets for oil and maize, allowing transport and fuel costs to influence maize prices, and suggest that international shocks to global product prices, including transport costs, can transmit to local market prices. Given the importance of transport costs in determining the volume of trade and the direction or travel route for trade, we implicitly reflect the impacts of transportation costs on bilateral trade following Behar and Venables (2010); Clark, Dollare, and Micco (2004); Limao and Venables (2001); and Nordas and Piermartini (2004)

[2]CIF/FOB represents Cost, Insurance, and Freight (CIF) and Free on Board (FOB), which give an estimate of border prices of importing and exporting countries. CIF prices are reported by the importing country, which estimates the cost of imports. FOB prices are reported by exporting country, and they refer to costs of shipping the products abroad from exporting borders (see Limao and Venables, 2001). CIF/FOB data are provided by IMF's Direction of Trade Statistics.

using the determinants of transport costs (i.e., distance, common border, and quality of infrastructure) in the gravity model of trade.

Improving trade facilitation and infrastructure are considered important way to enhance international trade flows. A study by Portugal-Perez and Wilson (2011) used trade data for 101 countries to estimate the impact of hard and soft infrastructure on the export volume of developing countries. In the empirical model, the authors used indices and indicators to represent the quality of physical infrastructure for ports, airports, roads, and railroads infrastructure, and used business environment and transport efficiency as measures for soft infrastructure. Results showed that improving physical infrastructure and business environments have large impacts on increasing export value.

Shepherd (2016) addresses the relationship between trade facilitation, infrastructure, and network connectivity for Sub-Saharan Africa (SSA) and other global and regional value chains. Shepherd used network analysis of value-added trade for agricultural, textile, and clothing sectors for 189 countries for years 1996 and 2011 to estimate value chain connectivity measures. The findings show that there is a large gap in trade of agricultural, textile, and clothing between SSA and other developing regions, the Pacific and East Asia. The author suggests that the enhancement of trade facilitation and infrastructure can improve trade flows and better connect SSA with global and regional value chains.

Another study by Wilson, Mann, and Otsuki (2004) evaluated the effects of port efficiency, customs, regulations, and service infrastructure on trade flows of manufacturing products. The authors show that trade volumes are positively influenced by the four measures of trade facilitation, with the largest impact being port efficiency. Mirza (2009) confirms that the gains to trading countries exceed the capital costs of investing in border infrastructure reforms in Sub-Saharan Africa with a benefit-cost ratio of 3.9%. Mirza (2009) also discusses that while infrastructure development projects require a substantial amount of capital and resources, the literature supports that improving hard and soft infrastructure can result in a comparative advantage for national and international trading pairs through the reduction of transport and shipment costs.

Investment in physical infrastructure and other trade facilitation can decrease transportation costs, specifically for low-income countries, which increases agricultural trade. Korinek and Sourdin (2010) used a gravity model and data on maritime transport costs to assess the impact of maritime shipping costs on the trade of aggregated and disaggregated agricultural goods. Results show that maritime freight costs represent more than 10% of the total cost for most agricultural product imports. Further, findings indicate that a reduction in transport costs, while controlling for shipping distance, can increase agricultural imports. Other studies also investigated the role of infrastructure on agricultural trade and suggest that good quantity and quality infrastructure in both rural and urban areas can enable agricultural and food product access to national and international markets (Felloni et al., 2001; Park, 2005; Ismail and Mahyideen, 2015).

Agricultural commodities are more commonly shipped by railroads and roads within the country, as this is known to have a cost advantage compared to air and sea transport. However, shipments to the global market are affected heavily by transaction costs at borders and the distance between countries. Thus, this study evaluated the relationship between food and agricultural trade and quality of roads, railroads, ports, and airports. Much of the literature that addresses the role of trade facilitation on international trade theoretically or empirically applies the standard gravity model of trade. The gravity model of trade was used for the first time by Jan Tinbergen in 1962. The basic traditional model includes variables such as the country's income level, distance, and other dummy variables (e.g., contiguity, common language, colonial history, free trade agreement). Later, the gravity model of trade was modified to include different economic forces that may enhance or restrict bilateral trade flows. The modeling approach was expanded to explain the variation in bilateral trade by including trade facilitation and infrastructure as non-policy barriers to trade (Limao and Venables, 2001; Anderson and Wincoop, 2004; Clark, Dollare, and Micco, 2004; Nordas and Piermartini, 2004; Francois and Manchin, 2007; Behar and Venables, 2010).

Data and Estimation

Data and Variables

We used a panel of aggregated agricultural bilateral trade data for 25 selected North and Latin American countries from 2006 to 2014.[3] Data on imports for food, animal, and vegetable sectors were collected for all possible pairs of the 25 countries in the sample. Then, the aggregation of the three sectors was used to represent the total aggregated agricultural sector. The data on import values and weighted tariff rates were collected from the World Integrated Trade Solution (World Bank, 2017). GDP, as a proxy for income, was obtained from the World Development Indicators Database. Data on distance, common language, and common border dummy variables were taken from the CEPII Database (CEPII, 2017). Data on preferential trade agreements were collected from the Foreign Trade Information System (SICE, 2017) and World Trade Organization (WTO, 2017). Transportation infrastructure indices were employed to represent the quality of hard infrastructure in the model and were obtained from the Global Competitiveness Reports from 2006-2014 (Schwab, 2014), which were provided by the World Economic Forum and Executive Opinion Survey. The data on infrastructure were represented in terms of weighted average quality, indices valued from 1 to 7, where 1 refers to a country with extremely underdeveloped infrastructure and 7 refers to a country with well-developed infrastructure, on average within the country. The data for Executive Opinion Survey was collected from 150 institutions around the world that have a partnership with the World Economic Forum. The Global Competitiveness Report specifies infrastructure as one of the basic requirements that fosters productivity and enhances economic growth. Accordingly, we included the overall hard infrastructure variable in the model with four modes of transport infrastructure comprised of the quality of roads, railroads, ports, and airports.

The World Integrated Trade Solution data show that several country pairs have zero trade flows or import values that have not been reported. We assumed that the observations with missing

[3]Sample countries are selected based on the availability of infrastructure indices data. We restricted our sample to 2006-2014, because most countries in the sample did not report import values for 2015, and there are many zero trade observations for most of the country pairs for years before 2006.

import values are zero trade flows as shown in the literature (Santos Silva and Tenreyro, 2006; Helpman, Melitz, and Rubinstein, 2008; Baldwin and Harrigan, 2011; Francois and Manchin, 2013). Moreover, data on applied bilateral tariff rates have not been consistently reported for some pairings. Therefore, we calculated missing values for applied tariff rates using a weighted average tariff rate formula.[4] On the other hand, there are a few infrastructure indices that are not reported by the Global Competitiveness Reports. We calculated the missing data using interpolation by considering the indices' trends over the most recent two years of available data.

Table 1 shows the comparison of transport infrastructure indices for the year 2014 for the representative sample countries that have either maximum or minimum index value in each index category. The United States has the highest quality of overall transport infrastructure among North and Latin America for 2014, with an index value equal to 5.82 for overall infrastructure, 6.1 for airports, 5.7 for roads, and 4.9 for railroads. While the minimum quality of overall transport infrastructure is for Venezuela, Panama has the highest quality of ports infrastructure among the sample countries for the year 2014. Countries with no railroads have a quality index value equal to zero.

Table 1. Comparison of Hard Infrastructure Indices among Selected North and Latin American Countries in 2014

	Median	**Minimum**	**Maximum**
Transport infrastructure index (1-7)	3.98 Brazil	2.65 Venezuela	5.82 United States
Roads index (1-7)	3.7 Guatemala and Jamaica	2.5 Paraguay	5.7 United States
Railroads index (1-7)	1.9 Costa Rica and Suriname	0.00 Trinidad and Tobago and Barbados	4.9 United States
Port index (1-7)	4.2 Trinidad and Tobago	2 Bolivia	6.3 Panama
Airport index (1-7)	4.1 Colombia and Guatemala	2.6 Paraguay	6.1 United States

Data source: World Economic Forum, Global Competitiveness Report, 2014.

Empirical Model

Following past literature, we modified the same basic traditional gravity model of trade to investigate the impact of infrastructure quality on agricultural bilateral trade flows. The model specification in terms of the Cobb-Douglas form is the following:

[4]Weighted average tariff rate for year t = ((tariff rate of year(t-1)* import value of year(t-1))+(tariff rate of year(t-2)* import value of year(t-2))/(import value of year(t-1)+ import value of year(t-2)). This formula provides a straightforward approach to calculate the missing import-tariff weighted averages; however, this method has possible limitations as it can underweight high tariffs.

$$M_{ijt} = \alpha_0 \, GDP_{it}^{\beta_1} \, GDP_{jt}^{\beta_2} \, D_{ijt}^{\beta_3} CB_{ijt}^{\beta_4} LG_{ijt}^{\beta_5} PTA_{ijt}^{\beta_6} (1 + \tau_{ijt})^{\beta_7} INF_{it}^{\beta_8} \, INF_{jt}^{\beta_9} \, \mathcal{E}_{ijt} \quad (1)$$

Taking the logarithm of the equation results in the following model:

$$ln\, M_{ijt} = \beta_0 + \beta_1 \, ln\, GDP_{it} + \beta_2 \, ln\, GDP_{jt} + \beta_3 \, ln\, D_{ijt} + \beta_4 CB_{ijt} + \beta_5 CL_{ijt} + \beta_6 PTA_{ijt}$$

$$+ \beta_7 \, ln\left(1 + \tau_{ijt}\right) + \beta_8 \, ln\, INF_{it} + \beta_9 \, ln\, INF_{jt} + \mu_{ijt} \quad (2)$$

Where i and j represents importing and exporting countries, respectively, M_{ijt} is the value of agricultural imports from country *i* to country *j* in thousands of U.S. dollars, *GDP* is gross domestic product in millions of U.S. dollars. D_{ijt} represents the distance between importing and exporting countries measured in kilometers. *CB*, *CL*, and *PTA* are dummy variables for common border, common language, and preferential trade agreement, respectively. The dummy variables equal 1 if the country pairs share a common border, speak a common language, or have a free trade agreement, and zero otherwise. τ_{ijt} is the weighted average effectively applied bilateral tariff rate. *INF* represents importer and exporter infrastructure indices corresponded to the quality of infrastructure. *INF* measures 5 different indices consisting of overall hard infrastructure, roads, railroads, ports, and airports. Finally, μ_{ijt} is the random error term.

Estimating the Gravity Model of Trade

It is often the case that certain country pairs do not trade with each other at all or for some timeframe. Therefore, we observed zero import values in agricultural trade data for some country pairs, especially when considering highly disaggregated products. Since the log of zero is undefined for log-linear models, zero trade observations become a problem when estimating the gravity model of trade using an Ordinary Least Squares (OLS) estimator. Many studies in this area argue that estimating the gravity model of trade while omitting zero trade observations results in a loss of important trade information and biased estimates (Linders and de Groot, 2006; Gómez-Herrera, 2013; Martin and Pham, 2015). Accordingly, the literature suggests that zero trade flows should be included in the model to deal with different empirical estimation problems (Linders and de Groot, 2006; Helpman, Melitz, and Rubinstein, 2008; Gómez-Herrera, 2013; Martin and Pham, 2015). The Heckman estimator, Tobit estimator, and Poisson Pseudo Maximum Likelihood (PPML) and Gamma Pseudo Maximum Likelihood (GPML) are examples of estimation methods that have been widely used to deal with zero trade values. This research employed a PPML estimation method to account for zero trade flows when estimating the impact of the quality of hard infrastructure on the import volume of annual agricultural trade. The PPML estimator is known to account for heteroskedasticity (Santos Silva and Tenreyro, 2006), can take advantage of the information contained in the zero trade flows, ensures that the gravity fixed effects are identical to their corresponding structural terms (Arvis and Shepherd, 2013; Fally, 2015), and results in unbiased as well as consistent estimators (Santos Silva and Tenreyro, 2006; Francois and Manchin, 2013; Gómez-Herrera, 2013).

PPML uses the level of trade values rather than the log of trade, and the interpretation of the estimated coefficients can represent simple elasticities. Santos Silva and Tenreyro (2006) specify the PPML model in terms of a constant elasticity of substitution (CES) form:

$$y_{ijt} = \exp\left(x_{ijt}\beta\right)\epsilon_{ijt} \tag{3}$$

where y_{ijt} is the import value; x_{ijt} is a vector of explanatory variables, β is the coefficient of explanatory variables, and ϵ_{ijt} is the error term, where $\left(\epsilon_{ijt}|x\right) = 1$. Taking the first-order conditions to solve for β, results in the following form:

$$\textstyle\sum_{i=1}^{N}\left[y_{ijt} - \exp\left(x_{ijt}\hat{\beta}\right)\right]x_{ijt} = 0 \tag{4}$$

This specification is estimated while assuming that the conditional variance is constant, and that the conditional variance is proportional to the conditional mean.[5] We estimated the model including all variables specified in equation 2 with the addition of importer and exporter time-varying fixed effects and exporter-importer time-invariant fixed effects.

With the PPML estimation method, our gravity model can be represented by the following form:

$$\begin{aligned} M_{ijt} = {} & \beta_0 + \beta_1 \, ln\, GDP_{it} + \beta_2 \, ln\, GDP_{jt} + \beta_3 \, ln\, D_{ijt} + \beta_4 CB_{ijt} + \beta_5 CL_{ijt} + \beta_6 PTA_{ijt} \\ & + \beta_7 \, ln\left(1 + \tau_{ijt}\right) + \beta_8 \, ln\, INF_{it} + \beta_9 \, ln\, INF_{jt} + \beta_{10} \sum D_i + \beta_{11} \sum D_j \\ & + \beta_{12} \sum \gamma_{ijt} + \mu_{ijt} \end{aligned} \tag{5}$$

where D_i (D_j) are the dummy variables of importing (exporting) countries, and γ_{ijt} is the time-varying fixed effects for a given trade pair in year t. In this study, we estimated 6 models, the basic model, and then 5 models each, including the basic model variables with the separate addition of infrastructure indices to the basic model (overall infrastructure, roads, railroads, ports, and airports).

We included time-varying fixed effects in the model to account for changes in trade costs and price indices between trading countries, which controls for country-specific multilateral resistance terms. Anderson and van Wincoop (2003) argue that omitting multilateral resistance terms from the gravity model of trade can result in biased estimates. However, Harrigan (1996) and Hummels (1999) used exporter and importer fixed effects in the gravity equation as a solution for omitting trade multilateral resistance terms. Feenstra (2002) argues that using either the fixed effects approach or multilateral resistance terms in the gravity model results in consistent estimates even though explicit multilateral resistance terms can result in more efficient estimates.

[5] This assumption says that $E(y_{ijt}|x) = \exp(x_{ijt}\beta) \propto V(y_{ijt}|x)$ (see Santos Silva and Tenreyro, 2006; para. 645.)

Empirical Results and Discussion

This section presents the results of the Poisson Pseudo Maximum Likelihood (PPML) estimated coefficients for the gravity model of agricultural trade. For each of the estimated gravity equations, we report 6 regressions, one for the basic model, one for the overall hard infrastructure index, and regression results for each mode of transport infrastructure, including roads, railroads, ports, and airports. The first column in Table 2 shows the estimated coefficients for the basic model. All the estimated coefficients are statistically significant except GDP estimates for exporting country. The estimated coefficient for the distance variable negatively influences agricultural import flows. A 1% reduction in the distance traveled would increase agricultural imports by approximately 0.7%, suggesting that a shorter travel route is expected to increase bilateral trade value. The coefficient of the common language variable has unexpected sign. This can be explained by the large number of zeros between trade partners that do not share a common language, or by other country pairs that have positive trade value but do not share a common language, which could result in a negative estimated coefficient for the common language variable.

The other five columns in Table 2 present the estimated coefficients for the quality of the four modes of physical infrastructure indices along with the overall hard infrastructure index. The quality of physical infrastructure has a positive impact on agricultural trade volume for both exporter and importer. Nevertheless, the estimated coefficient of exporters' transport infrastructure has a larger impact on trade flows than importers' transport infrastructure. This finding could be due to the higher costs that are incurred by producers in exporting countries while moving agricultural commodities from farm gates or processing factories to exporting borders, whereas importers ship the commodities from importing borders to domestic market centers. Hard infrastructure is assumed to be of higher quality in market centers compared to rural and agricultural areas. The estimated coefficients suggest that improving the quality of exporter and importer hard infrastructure by 10% is expected to increase agricultural trade flows by 8.9% and 5.4%, respectively. This means that investments in all physical infrastructure networks, including roads, railroads, ports, and airports, by reforming existing facilities and/or constructing new physical network systems are expected to lead to increased trade. Even though the results show that improving hard infrastructure positively influences agricultural bilateral trade, the advantages from such developments may differ from country to country based on the volume of agricultural trade, direction of bilateral trade, and the influence of other incentives on agricultural trade flows (e.g,. GDP level, low tariff rate, etc.).

Among the four indicators of hard infrastructure, the importers' and the exporters' ports index have the largest effects on the bilateral trade flows. This result is consistent with the finding by Nordas and Piermartini (2004), where they conclude that port infrastructure has the largest impact on bilateral trade, among all indicators of infrastructure. These large impacts can explain the importance of improving ports for countries that depend on sea transportation of agricultural commodities, especially for countries that do not share common land borders and use sea shipments for trading goods. Therefore, the investments in port infrastructure enhancement are assumed to have a large impact in agricultural bilateral trade among sample countries, given that all North and Latin American countries are coastal countries except Bolivia and Paraguay.

For roads infrastructure, the results imply that improving importer and exporter roads by 10% are expected to enhance agricultural trade flows by about 7.2% and 4.9%, respectively. Results indicate that most of the sample countries, especially among Latin American countries, depend heavily on road networks for agricultural bilateral trade because they share a common land border. Railroad indices have the smallest impacts on agricultural imports in the sample. The results suggest that improving the quality of importer and exporter railroads by 10% would increase trade volume by approximately 2.2% and 2.4%, respectively. This low impact could be due to the low quality of railroads in developing countries included in the study or because some countries have no railroad infrastructure (i.e., Barbados and Trinidad and Tobago).

Table 2. Hard Infrastructure Impacts on Agricultural Bilateral Trade, PPML Estimates

	Basic Model	**Infrastructure**	**Roads**	**Railroads**	**Ports**	**Airports**
Bilateral tariff rate	-0.1018*** (0.0254)	-0.0976*** (0.0271)	-0.1022*** (0.0251)	-0.0878*** (0.0235)	-0.0956*** (0.0256)	-0.1021*** (0.0250)
GDP importer	1.6122*** (0.3603)	2.0858*** (0.4336)	1.5587*** (0.4012)	1.7612*** (0.4017)	1.9247*** (0.3831)	1.5830*** (0.3612)
GDP exporter	0.3058 (0.3385)	0.1352 (0.4159)	0.1903 (0.3712)	0.2174 (0.3535)	0.1496 (0.3998)	0.3366 (0.3438)
Distance	-0.6875*** (0.0514)	-0.6879*** (0.0514)	-0.6875*** (0.0515)	-0.7672*** (0.0567)	-0.6879*** (0.0513)	-0.6874*** (0.0513)
PTA	0.7089*** (0.0601)	0.7100*** (0.0599)	0.7088*** (0.0602)	0.6951*** (0.0604)	0.7104*** (0.0599)	0.7088*** (0.0600)
Common Language	-0.8130*** (0.1199)	-0.8177*** (0.1201)	-0.8130*** (0.1197)	-1.1082*** (0.1375)	-0.8189*** (0.1202)	-0.8128*** (0.1197)
Common Border	0.7088*** (0.0715)	0.7114*** (0.0717)	0.7085*** (0.0712)	0.6967*** (0.0692)	0.7126*** (0.0716)	0.7087*** (0.0711)
Infrastructure importer		0.5410** (0.2330)				
Infrastructure exporter		0.8924*** (0.2246)				
Roads importer			0.7201*** (0.2451)			
Roads exporter			0.4886** (0.2011)			
Railroads importer				0.2179** (0.0865)		

Table 2. (continued)

	Basic Model	Infrastructure	Roads	Railroads	Ports	Airports
Railroads exporter				0.2403*** (0.0852)		
Ports importer					0.7655*** (0.2246)	
Ports exporter					0.6484*** (0.2026)	
Airports importer						0.7451*** (0.2559)
Airports exporter						0.4301* (0.2465)
Constant	-6.4574 (5.1961)	-9.4901 (6.4702)	-4.7868 (5.8633)	-6.1373 (5.7506)	-8.0174 (5.8281)	-6.6660 (5.1865)
Observations	4950	4950	4950	4185	4950	4950
Importer FE	Yes	Yes	Yes	Yes	Yes	Yes
Exporter FE	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R2	0.95	0.95	0.95	0.95	0.95	0.95
Wald chi2	71558.60	75297.45	70950.54	81440.44	75459.33	73028.04
Prob > chi2	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Source: Authors' estimates using Poisson Pseudo Maximum Likelihood (PPML) estimation.
Notes: All variables are in terms of log except the dummy variables; numbers in the parentheses are robust check standard error; the model estimated with addition of country dummy variables and time fixed effects; single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level.

Conclusion

Poor and inadequate quality network systems can be an impediment to international agricultural trade, which may increase transportation costs of food and agricultural shipments. Even though the quality of hard infrastructure varies across countries, the development of good quality physical infrastructure is expected to benefit both developing and developed countries by reducing transportation costs and positively influencing agricultural bilateral trade. This study estimated the impact of hard infrastructure on agricultural trade volumes. We employed a modified gravity model of trade using the Poisson Pseudo Maximum Likelihood estimator to understand the effects of the quality of physical infrastructure on agricultural bilateral trade among North and Latin American countries.

We found that the quality of physical infrastructure is positively related to agricultural bilateral trade. Results suggest that a 10% improvement in the quality of hard infrastructure is expected to increase agricultural trade by approximately 8.9% for exporting countries and by 5.4% for importing countries. The quality of roads and ports infrastructure has similar and large effects on agricultural bilateral trade. Port infrastructure is important for total agricultural trade because most of the sample countries are coastal and ship most products via water transport. Similarly, roads are important for food and agricultural product trade given that some countries in North and Latin America share an inland common border, such as the United States and Mexico, and Brazil and Colombia.

Poor-quality hard networks could be attributed to the intensive use of a transportation system over time without upgrading the damaged networks or adding new transportation systems. In addition, some countries experience different crises or natural disasters, which could lead to the deterioration of some physical infrastructure in the country at a given time. Improving the physical networks would require a substantial increase in project funding. However, increased investment in such projects may reduce delays and traffic in the roads and highway system and reduce maintenance costs for all modes of transport. Countries with low- to medium-quality ground networks, such as Suriname, Paraguay, Honduras, Guatemala, Costa Rica, and Brazil, may benefit from investing in repairing and expanding existing networks and building additional roads and railroads to expand the transportation capacity in each country. However, countries with high-quality hard infrastructure index values of 5 to 7, such as Canada and the United States, may also benefit from repairing and reforming existing physical networks while concentrating investment funds on railroads and roads, as they already have high-quality ports and airport systems.

Thus, the development of hard infrastructure for both exporting and importing countries is important to increase quantities traded, lower shipment costs, and help producers in rural areas have better access to domestic and international markets. This study only focused on assessing the impact of the quality of physical networks on trade flows. However, future research is warranted to evaluate and compare the costs of improving each transport mode relative to the benefits of increased agricultural trade, as countries may benefit from concentrating investment projects in developing the modes that are used more commonly to trade across the country and at the border. As results show, the large positive impact of the estimated results for ports indices suggests that it may be worthwhile to invest in developing port infrastructure from both importer and exporter perspectives, as this may result in increasing agricultural trade volumes for trading countries. In general, investments in hard infrastructure are expected to increase agricultural trade in both developed and developing countries. Even though developed countries have historically supported high-quality and well-developed networks, overall, there may be a deterioration of some hard infrastructure facilities over time in specific areas around the country where physical infrastructure is intensively used for transportation. Therefore, investments in improving roads, railroads, airports, and ports, or building new network systems are essential as one method that may increase trade of agricultural commodities between North and Latin American countries.

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