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THE INFLUENCE OF INFRASTRUCTURE ON TRADE IN LATIN AMERICAN COUNTRIES IN THE SHORT AND LONG RUN

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Abstract: Infrastructure plays an important role in international trade, explaining not only the costs of trade but also its effects upon growth and economic development. When combined with geographical conditions, such as distance, infrastructure provides a solid explanation for bilateral trade flows. The aim of this paper is to estimate the influence of infrastructure on trade in Latin American countries in both the short and long run using a gravity model based on panel data for the period between 2006 and 2013. The sample consists of the main trading partners of Latin America, a total of 74 countries, using the least squares dummy variable (LSDV) and the Poisson pseudo-maximum likelihood (PPML) as estimators. The results showed that general infrastructure and the exporters' ports affected trade positively in the short run. In the long run, improvements in the overall infrastructure of both the exporter and importer countries and the port of the importing country are the most relevant factors in increasing Latin American imports.
Key Words: Infrastructure. Latin America. International Trade. Gravity Model.

Resumo: A infraestrutura desempenha um papel importante no comércio internacional. Ela explica não apenas os custos do comércio, mas também seus efeitos sobre o crescimento e o desenvolvimento econômico. Além disso, quando combinado com condições geográficas, como a distância, fornece uma explicação muito sólida para os fluxos de comércio bilateral. Nesse sentido, o objetivo deste artigo é estimar a influência da infraestrutura no comércio dos principais países da América Latina, tanto a curto quanto a longo prazo, utilizando um modelo gravitacional baseado em painel de dados para o período entre 2006 e 2013. A amostra compreende os principais parceiros comerciais da América Latina no mundo, que somam 74 países, utilizando o estimador de efeitos fixos (LSDV) e a Pseudo Máxima Verossimilhança de Poisson (PMVP) como estimadores. Os resultados mostraram que a infraestrutura geral e os portos do exportador afetaram positivamente o comércio no curto prazo. No longo prazo, as melhorias na infra-estrutura geral, tanto para o país exportador quanto para o importador, e o porto do país importador são os canais mais relevantes para aumentar as importações latino-americanas.
Palavras-chave: Infraestrutura. América Latina. Comércio Internacional. Modelo Gravitacional.

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1 INTRODUCTION

There is a growing body of literature about the effects of infrastructure on international trade, spurred by the seminal studies of Bougheas et al. (1999) and Limão and Venables (2001). There are two potential biases regarding the functions of infrastructure, as Calderón and Sérven (2004) emphasized. The first concerns social infrastructure, that is, household and population welfare related to the expansion of trade reach and assistance to less economically and socially developed regions. The second bias concerns productive capital and its interrelations with other regions in the country and abroad, through gains in competitiveness, cost reduction and productivity improvement.

Regarding Latin American countries, Tomassian et al. (2010) emphasized that an efficient infrastructure is one of the most important means to promote national development policies and regional integration. Nonexistent or inefficient infrastructure, as usually occurs in Latin American countries, makes it difficult for these countries to achieve stability, economic growth, social development and integration of the countries in the region. Despite its importance, public investment in infrastructure in the region has declined since the 1980s, when it comprised 3% of the gross domestic product (GDP), compared with the beginning of the 21st century. Private investments have not been sufficient to replace the levels observed in the 1980s.

A recovery of Latin America's infrastructure may stimulate a broader regional integration, bringing these countries together as important international players into global trade networks. The purpose of this article is to estimate the influence of infrastructure on trade in Latin American countries using a gravity model based on panel-data for the period between 2006 and 2013. The sample consists of the main trading partners of Latin America, totaling 74 countries[1], using the least squares dummy variable (LSDV) and the Poisson pseudo-maximum likelihood (PPML) as estimators. The main contribution of this article is the estimation of the effects of infrastructure in Latin America in both the short and long term. The hierarchical model adopted by the LSDV estimation assumes that infrastructure is constant over time (long term), while in the PPML, it is variable in each year of the sample (short term).

The remainder of the paper is organized as follows. The second section analyzes empirical studies that used the gravity model to relate infrastructure to international trade in different regions in the world. The third section presents the empirical strategy used, the estimated model, and the databases and their sources. The fourth section discusses the results, and the last section concludes.

2 INFRASTRUCTURE EFFECTS ON INTERNATIONAL TRADE

Studies examining the relationship between infrastructure and trade became increasingly common after the 1990s, when many developing countries pursued more liberal trade policies. Portugal-Perez and Wilson (2012) indicated that, in an environment of continuous tariff reductions, policies favoring transaction cost reductions for exporters and importers are relevant to developing countries[2].

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[1] The list of countries is in Annex 1.

[2] The successive rounds of trade negotiations under the umbrella of the General Agreement on Trade and Tariffs (GATT) and subsequently the World Trade Organization (WTO), in addition to the proliferation of regional and bilateral preferential trade agreements (PTAs), have led to considerable declines in tariff barriers.

Geographical determinants, such as distance, access to the sea and infrastructure quality, affect countries' participation in international trade. Calderón and Servén (2004) emphasized infrastructure as an important component in trade liberalization in developing countries. According to the authors, an efficient infrastructure allows people in vulnerable and underdeveloped regions to benefit from the opportunities and services offered by more developed economies.

According to Venables and Limão (2002), an unfavorable geography associated with an inefficient infrastructure can lead to high transport costs for developing countries, harming or inhibiting their participation in trade[3]. On the other hand, an efficient infrastructure would alleviate the problems caused by geography and would increase trade gains through cost reductions. Limão and Venables (2001) pointed out that distance alone cannot explain trade costs, as domestic infrastructure and transit infrastructure in noncoastal countries, for instance, would be as relevant as distance[4].

According to Portugal-Perez and Wilson (2012), there is no clear definition of trade facilitation measures related to infrastructure. However, most author associate "hard" infrastructure with within countries improvements in highways, railroads, ports, etc., while "soft" infrastructure is associated with between countries enhancements, such as transparency, customs efficiency and institutional reforms. One key issue is the sort of infrastructure (hard or soft) that matter most for international trade. There is evidence that improvements in both results in increases in trade flows, but enhancements in hard infrastructure leads to gains greater than reductions in tariff barriers and soft infrastructure, according to Shepherd and Wilson (2007) and Kockzan and Plecanov (2013). And improvements on within countries hard infrastructure is even more important in the case of landlocked countries, where the literature identified greater dependence on the terrestrial infrastructure of their neighbors (Limão; Venables, 2001, Cosar; Demir, 2014; Grigoriou, 2007; Shepherd; Wilson, 2007).

Despite the evidence of the benefits of infrastructure to both growth and trade, Latin American countries reduced their investments in infrastructure due to the macroeconomic crisis during the 1980s and 1990s. According to Easterly and Sérven (2003), fiscal adjustment programs and economic reforms have led to deep cuts in public investment in infrastructure. Santiago (2011) pointed out that, despite reforms that opened the infrastructure sector to private capital, there was little expansion of the physical infrastructure and a marked decline in its quality.

As a result, Sanchéz and Wilmsmeier (2005) found that transportation and trade costs in Latin American countries were 40% higher than the world average.[5] Furthermore, Barbero et al. (2015) emphasized that Latin America's overall infrastructure quality is among the worst in the world, lagging behind the Organization for Economic Cooperation and Development (OECD), eastern Europe and Central Asia, the Middle East and North Africa, and Southeast Asia. In addition to possessing one of the world's worst infrastructures, Latin America also has a geography unfavorable to trade, with the presence of mountain ranges, deserts and forests that cover entire continents in its interior, leading to negligible participation in world trade.

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[3] Hummels (2007) highlighted that empirical studies support the idea that transport costs are even greater barriers to trade than tariffs, especially for developing countries.

[4] Grigoriou and Carrere (2011) identified the distance from the main international economic areas and a deficient infrastructure in the countries in Central Asia as the main inhibitors of their participation in international trade.

[5] Barbero et al. (2015) have shown that an annual investment average of 5% of GDP would be required to meet the infrastructure stock deficit in the region; however, the average recorded has been around 3%, falling short of what is necessary.

2.1 EMPIRICAL STUDIES

Empirical studies relating infrastructure and international trade have used different approaches and strategies. This paper will focus only on those that employed the gravity model, as they examine the impacts that improvements in both the quantity and the quality of infrastructure exerted on trade.

Portugal-Perez and Wilson (2012) evaluated the impact of infrastructure quality on exports performance for 101 developing countries over the period 2004-2007. They divided infrastructure into four indexes (heavy - physical infrastructure and information technology, light – border and transport efficiency and business and regulatory environment). The authors found that both heavy and light infrastructure positively affected exports, but enhancements in physical infrastructure would provoke the greatest impact on exports, as the coefficient associated to this variable was the largest of all four. Ismail and Mahyideen (2015) validated the positive relationship between infrastructure and trade for select Asian countries, based on an augmented gravity model using random effects. The results showed that roads and ports play important roles in trade in both exporting and importing countries, with a 10% increase in road density increasing trade by 1%.

Shepherd and Wilson (2007) also analysed the impact of infrastructure quality on trade, examining how the development of highways in Central Asia and eastern Europe was associated with gains in trade flows. They demonstrated that an improvement in the quality of existing highways in the region would increase trade by up to 50%, especially in countries that serve as trade corridors. They also found that the effect of infrastructure on trade would be greater than the effect of tariff reductions and trade facilitation measures. Shepherd and Wilson (2009) also suggested that Southeast Asian trade would increase by 7.5% due to trade facilitation reforms, such as improving port quality. Cosar and Demir (2016) examined how enhancements in the quality of transport infrastructure in Turkey would affect the volume and composition of international and regional trade. They determined that transport infrastructure plays an important role in accessing international markets, and regions that are interconnected with transport infrastructure that lead to international trade have greater trade flows than those that are not directly linked. Celbis et al. (2015) estimated several meta-regression models, controlling for observed heterogeneity in terms of variation across different methodologies. They found that a 1% increase in infrastructure increases exports by approximately 0.6% and imports by approximately 0.3 percent.

Studies of Latin American countries also emphasize the benefits of improvements in infrastructure quality and quantity. Rojas et al. (2005), considering the Andean countries and their trading partners in the period 1993-1999, using a gravity model with cross sectional data, pointed out that a country's infrastructure is important not only to importing necessary goods but also to qualifying as a trade partner. Martinez-Zarzoso and Nowak-Lehmann (2003) employed a panel data framework to estimate the major determinants of Mercosur (plus Chile) and the 15 European Union members' trade flows over the period 1988-96.[6] They asserted that the level of infrastructure would be a relevant variable, but according to their results, only the exporter's infrastructure would increase trade. Blyde and Iberti (2014), examining the quality of Chilean roads, found that an improvement in quality that decreased transport costs an average of 16% would increase exports by 2%.

[6] The infrastructure variable was proxied by an index created by taking the mean of four variables: km of road, km of paved roads, km of railroads and telephone lines per person.

The infrastructure of transit and destination countries is as important as domestic infrastructure. Limão and Venables (2001) demonstrated that a poor transport infrastructure and an absence of outlets to the sea are harmful to trade. Moreover, landlocked countries experience reduced participation in trade, but this disadvantage can be minimized if the transport infrastructure is efficient along with the infrastructure of the country to which the goods are exported. Accordingly, Carrere and Grigoriou (2011) estimated the effects on trade of Central Asian countries and their partners, considering that most do not have coastal access. The authors determined that enhancements in infrastructure, considering only the internal territory, is not enough to eliminate the damage to trade caused by a lack of ocean access. In addition, the authors found that improvements in the infrastructure of transit countries would increase trade three times more in Central Asian countries than in other landlocked countries.

In addition to the stimulus that infrastructure provides to international trade through a reduction in trade costs, mainly transport costs, other studies investigated other links, such as the opening of markets, the creation of new comparative advantages or the strengthening of existing ones, and the relevance of reliable institutions. Koczan and Plekhanov (2013) considered the influence of physical infrastructure and partner countries' internal institutions on trade flows. The authors found that the gains are widened in a context of enhancements in infrastructure in the presence of efficient institutions, when tariffs are already reduced.[7]

This section showed that infrastructure has served as a tool for the cohesion of trade contiguity between national and regional spaces, both near and far. An efficient infrastructure would be reflected in trade growth between these regions, now interconnected, greater competition between firms and a greater supply of services for the population of these localities. Infrastructure unlocks opportunities for trade, since it provides the population and government access to resources previously unavailable.

3 EMPIRICAL STRATEGY

In this paper, the gravity equation was used to measure the effects of infrastructure on trade, following Limão and Venables (2001), Carrere and Grigoriou (2011) and Ismail and Mahyideen (2015). This study differs from the others because it estimates the effects of infrastructure on trade in both the short and long run over the period 2006-2013[8] for select Latin American countries. As infrastructure changes very little in the short run, defining whether infrastructure is fixed or variable in the short term is a very controversial issue. Thus, two regressions were estimated[9]. The least squares *dummy* variable (LSDV) model, detailed below, assumed infrastructure constant over

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[7] Saputra (2014) estimated the effects of regionalism and infrastructure on intra- and extra-regional trade flows for ASEAN countries. The author confirmed that these effects were positive, finding evidence that free trade and infrastructure allowed for trade gains among ASEAN countries.

[8] The delimitation of this period is due to the infrastructure information provided by the Global Competitiveness Index (GCI) and prepared by the World Economic Forum (WEF), in addition to a lack of more recent data about imports from the countries examined.

[9] Working with short-term infrastructure is justified by the statistical architecture chosen for the estimates, because a static panel containing a sample of 8 years of observations will be used for each pair of countries analyzed. For a sample with a larger number of years, one should evaluate if there is cointegration in the variables used and, thus, consider infrastructure in the long term.

time, whereas infrastructure was considered variable in the Poisson pseudo-maximum likelihood (PPML) model.

In addition, both estimation strategies use static panels, including two fixed effects, one for each country-pair and the other for each year, which, according to Cheng and Wall (2005), is the best way to specify the fixed effect. The fixed effect (a_{ij}) is inserted into the model to capture all the observed and unobserved characteristics that are constant over time but that influence trade flows. However, when the fixed effect is inserted into the equation, it is not possible to measure the observable variables that are commonly in the gravity equation, such as the distance between countries, the importer and exporter's territorial areas, and the border and common language *dummies*[10]. Historical, cultural or political ties and the possibility of the countries being natural trading partners are other factors also considered. The fixed effect (a_t) captures unobserved shocks, common to all countries, occurring in each period *t* and not perceived by the other variables in the model, but which can also determine changes in trade flows, such as business cycle, climatic factors, and wars, among others. Including these two fixed effects in the estimates, according to Anderson and Wincoop (2003), mitigates the risk of bias by considering the potential effects of natural trading partners, multilateral resistance and country isolation, and addresses bilateral heterogeneity.

To solve the problem of the impossibility of measuring the impact of variables constant in time, one can use a hierarchical model applied to the gravity equation, using two levels of estimates. Intuitively, this method establishes an order for the estimation of the coefficients that are related to the variables that are not constant in time, such as GDP, population and the *dummies* of the preferential trade agreements (PTAs), in a panel data model on the first level and to the variables constant in time, such as distance, border *dummies*, and language, among others, in the second level model. From the parameter vector calculated in the first level model, the second level model is constructed, which, in this case, will be a cross-section in which the regressors are the variables constant in time and the dependent variable is the fixed effect (a_{ij}) obtained in the first level. Formally, equation (1) presents the first level of the hierarchical model to be estimated:

$$m_{ijt} = \alpha_0 + a_t + a_{ij} + X_{ijt}\beta_k + \varepsilon_{ijt} \tag{1}$$

where m_{ijt} is the scalar representing the imports of Latin American country *i*[11] from the exporter *j* at time *t*; α_0 is the scale of the intercept common to all years and pairs of countries *ij*; a_t is the scalar of the specific fixed effect of each year *t* which also affects all pairs of countries *ij*; a_{ij} is the country-pair fixed effect; X_{ijt} is a line vector of the *1xK* dimension of the *k* explanatory variables of the model, for importers *i* and exporters *j* in year *t*; β_k is a parameter vector *Kx1* to be estimated; and ε_{ijt} is the scalar of the idiosyncratic error. Equation (1) is estimated by LSDV. The sample is composed of only 60 from the expanded sample of 74 exporting countries used in the PPML estimation. These 14 countries were removed from the sample because they did not

[10]Although these variables are indirectly present in the estimates, as part of the fixed effect *a_ij*.

[11] As a dependent variable, bilateral imports were chosen instead of exports, because Baldwin and Taglioni (2006) and Magee (2008) emphasized their high degree of reliability, as countries tend to report this information more precisely to control the evasion of foreign exchange.

export to at least one of the 15 Latin American countries during the period, generating a total of 7,200 observations (15 importing countries x 60 exporting countries x 8 years).

The second level of the model is estimated by ordinary least squares (OLS) and can be represented according to equation (2). To remain constant over time in the hierarchical model, the index was constructed by taking the mean of the annual variables that measure the effects of infrastructure on trade, as described in section 3.1, and inserting it in the second level[12] equation that follows:

$$a_{ij} = \eta_0 + \sum_{m=1}^{M} \eta_m \psi_{ij} + \tau_{ij} \quad (2)$$

where a_{ij} is the scalar of the country-pair fixed effect, estimated by equation (1); ψ_{ij} is the set of observable variables *m*, constant over time, but that could not be inserted in the first level of the model; η_m are the parameters to be estimated; and τ_{ij} is the scalar of the random error.

The second model, which assumes that infrastructure is variable in the short term, used the nonlinear[13] PPML as the estimator, expressed by equation (3).

$$m_{ijt} = \exp\left[a_t + a_{ij} + \sum_{k=1}^{K} \beta_k X_{ijt}\right]\varepsilon_{ijt} \quad (3)$$

where the variables follow the same notations previously defined. m_{ijt} is the scalar representing the imports of 15 Latin American countries *i* from 74 exporting partners *j* over the period 2006-13, comprising 8,880 observations.

3.1 VARIABLES AND DATA SOURCE

Following the standard procedures adopted in the gravity model and in the empirical review that relates infrastructure to international trade, variables have been inserted that act as proxies of trade stimulus, such as GDP and population, referring to the density of bilateral trade, and expansion proxies and trade restriction, referring to the geography of the countries. The proxy chosen for the infrastructure data was the Global Competitiveness Index (GCI), obtained from a survey of the economic and

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[12] In the PPML model, the infrastructure variables did not undergo any kind of treatment and, therefore, they vary in time. Thus, the difference in the two approaches arises from the treatment given to the variables of interest.

[13] Although this article does not aim to identify which estimator is the most appropriate for the gravity model, two different estimators were used to provide a more robust analysis. Santos Silva and Tenreyro (2006) and Magee (2008) suggest the use of the PPML estimator, whereas Cheng and Wall (2005) and Baldwin and Taglioni (2006) worked with the LSDV estimator. However, it should be noted that, only under the weak assumption that the gravity model contains a correct set of explanatory variables, Santos Silva and Tenreyro (2006) proposed to estimate the gravity equation through PPML because, according to them, PPML provides estimates of the consistent parameters even when the errors are heteroscedastic, in addition to allowing in the estimates bilateral trade flows with values equal to zero. Thus, since the PPML estimator allows the inclusion of zero flows in the estimations, the Poisson model database is composed of the 74 main partners in Latin America, while the hierarchical model was estimated excluding countries with zero bilateral flow, resulting in a sample of 60 countries.

productive sectors of the selected countries[14]. This variable was used as an infrastructure proxy by Ismail and Mahydeen (2015), among others. Chart 1 shows the series and variables used in the regressions, as well as the unit, the periodicity and their respective sources.

Regarding the infrastructure variables, *Infger* covers, in addition to the transport infrastructure, the supply of electricity and telecommunications, such as fixed and mobile telephone and internet access. The variable *Road*, referring to the quality of the highways, was chosen because it is the predominant mode of transport in Latin American countries. The variable *Port* was selected due to its relevance to the region's trade with outside countries.

Latin America consists of 33 countries divided into North, Central and South America. In general, the countries' exports are relatively homogenous and nontechnological, whereas their imports are much more diversified and technological. The 74 countries in the expanded sample used by the PPML model represented more than 80% of world trade during the period, with an average of 86.1%, indicating that the sample is representative of global trade.

Chart 1: Variables and databases

Series	Variable	Unit	Frequency	Database
Bilateral imports	*Imp*	US$	Annual	UNCTAD
GDP	*Gdp*	US$	Annual	UNCTAD
Population	*Pop*	Millions	Annual	World Bank
Distance	*Dist*	km	----	CEPII[15]
Isolation of the importing country	*Isso*	km	----	CEPII/UNCTAD
Importer and exporter area	*Area*	km^2	----	CEPII
Quality of the general infrastructure of the importing and exporting country	*Infger*	Index	Annual	GCI/WEF
Quality of the highways of the importing and exporting country	*Road*	Index	Annual	GCI/WEF
Quality of ports of the importing and exporting country	*Port.*	Index	Annual	GCI/WEF
Land border	Adj.	Dummy	----	CEPII
Coastal access	Lit	Dummy	----	CEPII
Common language	Lang	Dummy	----	CEPII
Participation in PTAs - MERCOSUR	Mercosur	Dummy	----	WTO

Source: Prepared by the authors.

The sample consists of 15 Latin American countries, shown in Table 1, with their respective shares of total imports in the region. The countries selected represent more than 90% of the imports in the region for each year analyzed. In addition to their relevance in total imports, the countries selected presented complete infrastructure

[14] This research analyzes the performance of approximately 140 countries on 12 pillars of competitiveness. The respondents are asked to analyze the business environment of their country, assigning the value of 1 for the worst-case scenario and 7 for the best.
[15] Centre d'Etudes Prospectives et d'Informations Internationales.

data for the whole period 2006-2013 from the GCI database (2015-2016) (Schwab and Sala-i-Martín, 2015).

Table 1: Countries selected for Latin America - share of imports in relation to total Latin American imports (%) - 2006-2013

Countries/Year	2006	2007	2008	2009	2010	2011	2012	2013
Argentina	6	6	7	6	7	7	6	7
Brazil	17	18	21	22	24	24	23	24
Chile	6	6	7	6	7	7	7	7
Colombia	4	4	4	5	5	5	5	5
Costa Rica	1	1	1	1	1	1	1	1
Ecuador	2	2	2	2	2	2	2	2
El Salvador	1	1	1	1	1	1	1	1
Guatemala	2	2	1	2	1	1	1	1
Mexico	39	36	32	32	32	30	30	30
Panama	2	2	2	2	2	2	2	2
Paraguay	1	1	1	1	1	1	1	1
Peru	3	3	3	3	3	3	4	4
Dominican Republic	2	2	1	1	2	2	2	1
Uruguay	1	1	1	1	1	1	1	1
Venezuela	6	7	6	7	5	5	6	6
Latin America Total	91	92	92	92	93	93	93	93

Source: Prepared by the authors with data from UNCTAD (2019).

The share of imports from the countries in the sample remained relatively stable over the years, except for Brazil, which increased its share of imports from 17% in 2006 to 24% in 2013, and Mexico, which reduced its share from 39% to 30% in the same period. Moreover, since the 2008-2009 international economic crisis and the subsequent end of the commodities boom, some countries in the region have faced external economic problems, such as declining exports and imports, deteriorating terms of trade, trade deficits and currency devaluations. This current trend reinforces the need to strengthen the region's infrastructure to increase its participation in world trade.

3.2 SPECIFICATION TESTS

Tests were performed to determine the best way to estimate the gravity model used in this paper. When there is heterogeneity in the model, the Hausman test is the best way to treat the non-observed component (*αij*), either by random or fixed effects. The idea is to identify if the unobserved component *αij* is related to the matrix regressors *Xijt*. If there is no correlation between the regressors and the unobserved component, the random effects estimator is the most efficient; otherwise, the fixed effects estimator should be used to avoid obtaining biased estimates. Formally, the null hypothesis (*H0*) of the Hausman test indicates that the non-observed component and the regressors are not related. Thus, given the rejection of *H0,* as indicated in Table 2, one should consider using the fixed effects model. This table also includes other tests related to the residuals of the model, applied from estimation of the LSDV estimator.

Table 2: Model specification tests

Tests	Value	P-value
Hausman Test: χ^2 (17)	244.82	0.0000
Modified Wald test for groupwise heteroscedasticity: χ^2(1107)	1.5e+07	0.0000
Wooldridge Autocorrelation Test: F(1, 1090)	21.681	0.0000

Source: Prepared by the authors from Stata 14.

From the rejection of the null hypothesis, one can detect the existence of heteroscedastic errors and autocorrelation of the residuals. Thus, to infer the estimated parameters, robust standard errors were used in both estimations, obtained through a robust covariance matrix, and, therefore, the presence of heteroscedasticity and serial autocorrelation of the residuals were considered. Note that standard errors are asymptotically valid in the presence of any type of heteroscedasticity, including cases of homoscedasticity and non-autocorrelated residuals.

4 RESULTS

As mentioned in the previous section, two models were estimated. In the PPML model, the infrastructure variables were variable over time (short term), whereas in the estimation via LSDV (long term), the average of these variables was taken; therefore, the variables became constant over time and were then inserted into the second level model[16]. Thus, the need for two approaches arose solely from the treatment of the variable of interest.

4.1 EFFECTS OF INFRASTRUCTURE IN THE SHORT TERM

According to the PPML model, the coefficients presented the expected results (Table 3). The GDP of the importing country affects bilateral trade by a magnitude comparable to that of the exporting country. In both cases, the coefficients were positive and significant. However, population does not significantly affect the bilateral flow within the region in either country. These results align with those obtained by Magee (2008) and Santos Silva and Tenreyro (2006). The isolation of the importing country, a proxy for multilateral trade resistance, showed a statistically significant negative coefficient, confirming predictions that the more isolated countries are, the less integrated they are into international trade. For the Southern Common Market (Mercosur)[17], the effects were not significant, showing that trade was not impacted in that region.

[16] As already mentioned in the previous section, the LSDV and PPML estimators, via fixed effects, omit variables that are constant over time.
[17] Members of Mercosur: Argentina, Brazil, Paraguay, Uruguay and Venezuela.

Table 3: Effects on Latin American imports from major trading partners (short run)

Variables	Fixed Effects – 1st level		PPML	
	Coef.	σ	Coef.	σ
GDP of the importer	0.643	0.000*	0.353	0.000*
GDP of the exporter	0.186	0.034**	0.327	0.000*
Population of the importer	2.010	0.104	-.015	0.983
Population of the exporter	0.970	0.102	-.505	0.414
Isolation of the importer	-12.37	0.000*	-6.31	0.000*
General infrastructure of the importer	--	--	0.379	0.036**
General infrastructure of the exporter	--	--	-.875	0.001*
Highway of the importer	--	--	-.114	0.286
Highway of the exporter	--	--	0.166	0.402
Port of the importer	--	--	0.002	0.984
Port of the exporter	--	--	0.856	0.000*
Mercosur	-.573	0.313	0.071	0.384
DA2007	0.251	0.000*	0.173	0.000*
DA2008	0.550	0.000*	0.395	0.000*
DA2009	0.368	0.000*	0.205	0.004*
DA2010	0.602	0.000*	0.431	0.000*
DA2011	0.932	0.000*	0.655	0.000*
DA2012	0.975	0.000*	0.722	0.000*
DA2013	0.868	0.000*	0.697	0.000*
Constant	59.7	0.006*	--	--
Number of observations	7,200		8,880	
F(15, 899)	80.39 [0.0000]			
Wald X^2 (19)			2578.97 [0.0000]	

Source: Prepared by the authors from Stata 14. Notes: (*), (**) and (***) correspond to the confidence level of 99%, 95% and 90%, respectively.

Regarding the infrastructure variables, the statistically significant coefficients provide relevant information. The general infrastructure of the Latin American importing countries has proved to be important in expanding trade flows between the region and its exporting partners in the short run. This result suggests that the overall infrastructure, that is, the infrastructure of transport, telecommunications and energy sectors, positively influences the region's imports in the short term. The effect of the exporting countries' ports on Latin American imports also showed a positive and significant coefficient.

However, the overall infrastructure of the exporting country has been shown to negatively affect trade. According to Tomassian et al. (2010), better infrastructure leads to increased mobility and trade flows between countries that already have an integrated infrastructure. As a result, exporting countries may have higher levels of trade with their so-called natural trading partners, generally geographically closer, as pointed out by Frankel (1997)[18]. Therefore, improvements in the general infrastructure of exporters would reduce their exports to Latin America, at least in the short term.

There is disagreement in the literature about the effects of infrastructure on the two directions of bilateral trade, as related by Celbis et al. (2015). On the one hand, previous studies of Latin American countries, employing both quality and quantity indexes to measure the impact of infrastructure on trade, emphasized that the exporter's infrastructure was more important in stimulating the region's trade. Martinez-Zarzoso and Nowak-Lehmann (2003), for instance, analyzing Mercosur-European

[18] Hummels (2007) points out that trade occurs significantly with partners up to 3,000 kilometers in distance.

Union bilateral trade, found that only the exporter's infrastructure would increase trade. Blyde and Iberti (2014) also stressed that improvements in the quality of Chilean roads would benefit most exports. Koczan and Plekhanov (2013) and Ismail and Mahyideen (2015) also found that the infrastructure and institutions of exporting countries had a greater impact on trade in other regions. On the other hand, Limão and Venables (2001) concluded that both the importer and exporter's infrastructures had positive effects on bilateral trade flows. Grigoriou (2007) also concluded that the transport costs of both partners are relevant in trade performance.

4.2 EFFECTS OF INFRASTRUCTURE IN THE LONG TERM

The results of the second level of the hierarchical model, presented in Table 4, are relatively close to what was expected. Distance shows a negative coefficient and is significant at a 90% confidence level. Adjacency shows a positive and quite significant coefficient, indicating that countries with common borders tend to market more. The importer area showed a negative and significant coefficient, confirming that the larger the importer area, the less dependent it will be on foreign trade, whereas the area of the exporting country has not been shown to significantly affect trade flows. Finally, as expected, common language also facilitates business and increases the possibility of trade. The effects of distance (Frankel, 1997) and the isolation of the importing country (Carrere and Grigoriou, 2011) on trade have been confirmed for countries in Latin America.

Table 4: Results of the second level model

Variables	Hierarchical model	
	Coef.	σ
Distance	-0.346	0.084***
Adjacency	2.071	0.000*
Area of the importer	-0.468	0.060***
Area of the exporter	-0.092	0.157
Common language	2.332	0.000*
General infrastructure of the importer	3.685	0.000*
General infrastructure of the exporter	5.964	0.000*
Highway of the importer	-6.624	0.000*
Highway of the exporter	-1.237	0.028**
Port of the importer	7.461	0.000*
Port of the exporter	-0.301	0.688
Constant	-0.789	0.703
Number of observations	900	
R^2	0.4353	
F(11,899)	70.68 [0.0000]	

Source: Prepared by the authors from Stata 14. Notes: (*), (**) and (***) correspond to the confidence level of 99%, 95% and 90%, respectively.

The results indicate that the quality of the overall infrastructure in both the exporter and importer countries positively affects Latin American bilateral imports in the long term. Thus, increasing the quality of the region's infrastructure may increase the region's share of world trade. These results are in line with previous studies of Latin American countries. Rojas et al. (2005), examining the Andean countries in the period 1993-1999, stressed that a country's infrastructure is very important for importing necessary goods and for qualifying as a trade partner.

Donaubauer et al. (2015) found greater effects on trade by variables such as telecommunications in relation to the transport variables. In Ismail and Mahyideen (2015), the telecommunications and information sectors presented the greatest significance. Thus, the relationship between trade and the general infrastructure variable, which includes telecommunications and information technology, is confirmed in these studies.

The results for the port variable in the long run were the opposite of what was observed in the short run. In the long term, the importing country’s port appears relevant to increasing trade in Latin American countries, while the exporting country’s port seems to have no effect. These results have important implications, as ports are the primary means of transporting goods between Latin America and the rest of the world. Thus, in the long run, improvements in the quality of Latin American ports would increase imports from its major trading partners.

The highways of both the importer and exporter presented significant and negative coefficients. This result may be related to the trade patterns of Latin American countries; the majority of countries in the sample export goods predominantly by sea. Thus, improvements in the highways would not spur trade, but instead would generate a negative impact. Improvements in the road network of Latin American countries would divert foreign trade to internal trade, as this transport mode prevails in the region. In addition, the presence of a significant expanse of forests and the Andes mountain range, and an outward-oriented development of modals, may help to explain the results found regarding Latin American highways. This result is consistent with the relationship investigated by Limão and Venables (2001), who pointed out the importance of geography and infrastructure to costs, damaging international trade.

5 CONCLUSIONS

The results confirmed that infrastructure affects Latin American international trade. General infrastructure, including telecommunications, energy and transport, positively influenced trade in both the short term, through PPML (importing country), and the long term, via fixed hierarchical effects, confirming its influence on trade. The exception was the negative effect found for the exporter in the short term, which could be explained if improvements in infrastructure lead to an increase in trade of the exporting countries with their natural partners, who are geographically closer. Given that trade in Latin America occurs mainly with transoceanic partners, improvements in the infrastructure of exporters would stimulate, at least in the short term, trade among them, at the expense of exports to Latin America.

The importer's port also had a positive effect on trade in the long term, given that trade occurs predominantly through this mode. Thus, ports’ modernization, incorporating new technological and telecommunications tools, can connect, in a more participative way, Latin American trade to the world. The results suggest that regional integration may alleviate problems of regional inefficiency, as suggested by Brooks (2008) and Carrere and Grigoriou (2011). Lastly, the study pointed out the negative effect of roads, in both the importing and exporting countries, in the long term. In the case of the importing country, a significant expanse of forests and the Andes mountain range, in addition to an outward-oriented development of modals (ports), could explain the result. In the case of the exporter, improvements in highways may lead to an increase in trade between the exporting countries and their geographically close trading partners, at the expense of exports to Latin America.

The effects of infrastructure for Latin America are aligned with other research, considering their particularities and regions of study. The infrastructure variables considered had ambiguous effects on trade in Latin America, according to the literature. Despite the ambiguity of some of the results in the short and long term, the importance of improving the general infrastructure and the importers' ports (Latin American countries) in the long term is evident, to leverage trade in the region. However, the macroeconomic crisis in Latin America has reduced infrastructure investment in the region. The recurring crises in the region in recent decades have generated one of the worst infrastructures in the world, disconnected regionally and internationally. Thus, in addition to geography and trade policy, infrastructure has been another impediment to Latin American trade.

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Annex 1: List of countries included in the sample

South Africa**	Denmark**	Italy**	Qatar
Germany**	Ecuador*	Japan**	United Kingdom**
Saudi Arabia	Egypt**	Jordan	Romania **
Algeria	United Arab Emirates **	Kuwait	Dominican Republic*
Argentina*	El Salvador*	Lithuania**	Russia**
Austria**	Slovakia**	Luxembourg	Siri Lanka **
Australia**	Slovenia	Malaysia**	Sweden**
Bahrain	Spain**	Mexico*	Switzerland**
Belgium**	U.S**	Morocco**	Thailand **
Brazil*	Estonia	New Zealand**	Tunisia
Bulgaria**	Philippines**	Nigeria	Turkey**
Canada**	Finland**	Norway**	Ukraine**
Kazakhstan	France**	Oman	Uruguay*
Chile*	Greece**	Netherlands /Holland **	Venezuela*
China**	Guatemala*	Pakistan**	Vietnam **
Colombia*	Hungary**	Panama*	
South Korea**	India**	Paraguay*	
Costa Rica*	Indonesia**	Peru*	
Croatia	Ireland**	Poland**	
Czech Republic**	Israel**	Portugal**	

Source: Prepared by the authors. Notes: (*) Latin American countries considered in both samples; (**) countries that presented positive trade for all the years considered.