A GRAVITY MODEL OF TRADE FOR ARGENTINA 2004-2017

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Abstract
This paper estimates a gravity model for Argentina during the period 2004-2017. Two versions were used: one using pooled ordinary least squares and another with fixed effects. The main results for the first model are as follows. On the one hand, income and the real exchange rate have the correct signs and are statistically significant. On the other hand, population and distance have negative effects, which is somewhat less known in the analysis of income and price elasticities. Regarding the second model, the results were not satisfactory. The income of trading partners, the real exchange rate, and population were not statistically significant, which contradicts economic theory.
Key words: *Argentina, Distance, Gravity, Population, Trade*

JEL Classification: *C31, F11, O20*

I. INTRODUCTION

The gravity equation in trade is one of the most robust empirical findings in international economics since the post-war period (Hall *et al*, 1979; Chaney, 2011). Bilateral trade between countries is expected to be positively related to the income level of each country and inversely related to the distance between them. These models are especially useful for modeling bilateral trade flows between two countries and advantageous for analyzing trade policy strategies (Bereciartua, 2005). Redding and Weinstein (2019) and Carrere et al. (2020) argue that the gravity equation, both as an empirical fact and theoretical construct, is one of the major recent findings in international trade research. Gravity models are based on the pioneering work of Tinbergen (1962) and Poyhonen (1963). The central idea is to apply to trade relations a concept analogous to Newton's Law (1687), which relates the attraction between two objects to the size of their mass and the distance between them (equation 1).

$$F = G\frac{m_1 * m_2}{r^2} \qquad (1)$$

Where *M* is the mass between two bodies and *r* is the distance. The universal law of gravitation states that the force exerted between two bodies with masses 1 and 2 at a distance *r* is equal to the product of their masses and inversely proportional to the square of the distance (G is a constant). Newton could not demonstrate his theory for lack of instruments and data, and it was only around the mid-19th century that it could be estimated (Sebastiá and Sebastiá, 2013). In economics, the so-called "*gravity equation*" is represented by the following equation:

$$T_{ij} = A\frac{Y_i Y_j}{D_{ij}} \qquad (2)$$

Where Tij are trade flows between countries (imports or exports are used); Yi is domestic income (GDPi), Yj is the income of the trading partner (GDPj), and Dij is distance (a proxy for transportation costs); *A* is a constant. These models usually assert that the bilateral trade flow between two countries is related to the size of their economies (measured by the level of their GDP and population), the distance between them, bilateral exchange rates, language, culture, etc. (Bergstrand, 1985; Shepherd, Doytchinova and Kravchenko, 2019).

The objective of the article is to perform an empirical exercise for Argentina during the period 2004-2017 and incorporate other explanatory variables into the trade models, such as population and distance, which generally do not usually appear in traditional studies. The research is organized as follows. Section 2 offers the theoretical framework and some studies for Latin America. Section 3 presents some stylized facts about trade flows in Argentina. Section 4 describes the estimation strategy and the results. Finally, Section 5 presents the conclusions.

II. THEORETICAL FRAMEWORK

II.A. Mathematical Models

Arkolakis *et al* (2012) begin their work with a challenging statement: the gains from trade are not as large as traditionally attributed in conventional studies. They develop a welfare function, W, which depends on two parameters. On one hand, the share of spending on domestic goods, which can be approximate as one minus the import penetration rate. On the other hand, ϵ, the elasticity of imports. Where (3) represents the change in welfare, while (4) denotes the variation in the share of domestic spending.

$$\widehat{W} = \frac{W^{'}}{W} = \hat{\lambda}^{1/\varepsilon} \quad (3)$$

$$\hat{\lambda} = \frac{\lambda^{'}}{\lambda} \quad (4)$$

Head and Mayer (2013) point out that gravity equations are models of bilateral interactions in which size and distance enter multiplicatively. There are three standard models to model the gravity equation.

1. *Model 1*. The first highlights the capacity of an exporter *i* to supply different markets. The variable *Zn* captures characteristics of the destination markets *n* that stimulate imports. The bilateral access of *n* to exporter *i* is captured by the parameter $0 \leq \phi_{ni} \leq 1$, while *G* is a constant.

$$X_{ni} = GS_i M_n \phi_{ni} \quad (5)$$

2. *Model 2*. The second focuses on production values, the importers' expenditure, and multilateral resistance. Where *Yi* is the production value, *Ej* is the importer's expenditure across all countries, while Π*i* and *Pj* are two terms associated with multilateral resistance represented as follows.

$$X_{ni} = \frac{Y_i}{\Omega_i}\frac{X_n}{\Phi_n}\varphi_{ni} \quad (6)$$

Where $Y_i = \sum_n X_{ni}$ is the value of production, $X_n = \sum_i X_{ni}$ is the value of the importer's expenditure in all countries, while Ω_i y Φ_n are two terms associated with multilateral resistance represented as follows.

$$\Phi_n = \sum_{\zeta} \frac{\varphi_{n\zeta} Y_{\zeta}}{\Omega_{\zeta}} \quad (7)$$

$$\Omega_i = \sum_{\zeta} \frac{\varphi_{\zeta i} X_{\zeta}}{\varphi_{\zeta}} \quad (8)$$

3. *Model 3*. The third is the best-known version and perhaps the most pedagogical graphically. It is known as the naive model. It is the most general version with the most restrictions. The assumption that que $a \neq b \neq 1$ is a generalization featured in Tinbergen's classical model (1962). This work employs Model 3 for the case of Argentina.

$$X_{ni} = GY_i^a Y_n^b \phi_{ni} \quad (9)$$

II.B. Empirical Studies

In Gravity models, the gravity equation has received little attention from the Latin American academic community. Below are some results, highlighting the scarcity of work related to the Argentine case. Cafiero (2005), using a fixed effects panel model for the period 1998-2002 for a set of countries, finds the following elasticities: gdpi=0.82; gdpj=0.17; popi=-0.52; popj=-2.01; reerij=0.11, where the independent variable is the imports of country i from country j. Jacobo (2010) estimated a trade equation using manufacturing exports from Mercosur to the European Union for a set of 16 countries between 1991 and 2004. He found that the income elasticity (Yi*Yj) was 0.80, while distance had an elasticity of -1.10, and population (popi and popj) had values of 0.16 and 0.13 respectively. Sangucho Cueva (2010) estimates a trade equation for Latin America obtaining elasticities of gdpij of 1.06 and dij of -0.25, while the real exchange rate (rrerij) has a negative sign of 0.051. Ávila Aguirre (2017) develops a gravity model for Colombia with respect to its main trading partners -49 countries- between 2000 and 2015. He estimates models using Pooled, Fixed Effects (FE), and Random Effects (RE), finding elasticities Yi and Yj of 1.7 and 1.2 respectively, while distance has a value of -1.98. Yaselga and Ilich Aguirre (2018) estimate a trade equation for Ecuador under three specifications: Pooled (grouped OLS), FE (Fixed Effects), and RE (Radom Effects) for 57 countries in the period 2007-2017. The elasticities obtained are like previous works (gdpj=0.87; gdpi=1.36; dij=-0.91, among others).

III. Stylized Facts

This section is based on Carrère (2020) to graphically show how gravity is related to factors such as geographical distance and other classic variables like language or colonial origins. Figure 1[1] describes the behavior of exports and imports, where it is observed that there is a close relationship between both variables, with an elasticity value of 0.877, slightly lower than what the literature supports (1.0). One of the main long-term determinants to be able to import is having the necessary foreign currency to pay for them, which is provided by exports (Bebczuk, 2008).

Figure 2[2] describes the relationship between the export-import ratio (x-axis) and geographical distance measured in km (y-axis), both in logarithmic scale. The 40 countries reported by INDEC as trade partners for the period 1990-2018 were taken. As academic literature points out, there is an inverse relationship between the variables: the greater the distance, the lower the trade. Additionally, it is noted that Latin American countries are located below the regression line (with gray markers), indicating that proximity is a source of trade.

Figure 3[3] describes the relationship between the language spoken in the country (a variable linked to culture and colonial origins) and the accumulated trade balance in millions of dollars. The black bars correspond to countries where Spanish is the official language, and the gray bars correspond to countries where a language other than Spanish is spoken (for example, Portuguese in Brazil; English in the United States, etc.). It is evident that the largest trade surpluses are obtained in Spanish-speaking countries, which constitute the majority of Latin America. Additionally, out of the 40 countries for which data is available, 28 have surpluses and only 12 have deficits, but 5 of these explain the total deficit (Brazil, United States, France, China, and Germany).

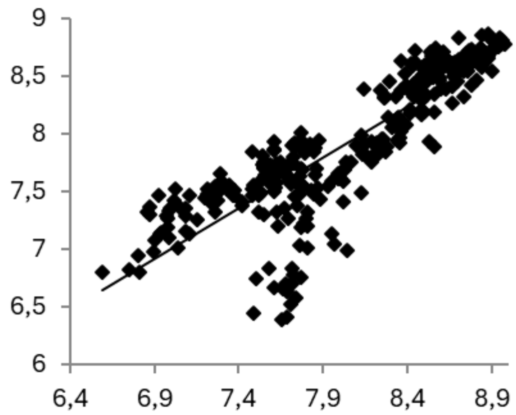

Figure 1. Relationship between exports and imports 1992-2017

[1] In Figure 1, the Y-axis corresponds to exports and the X-axis to imports, both in logarithmic scale

[2] In Figure 2, the Y-axis corresponds to geographical distance and the X-axis to the ratio between exports and imports, both in logarithmic scale.

[3] In Figure 3, the Y-axis corresponds to the trade balance in millions of dollars, and the X-axis corresponds to the country with which Argentina had trade between 2004 and 2017.

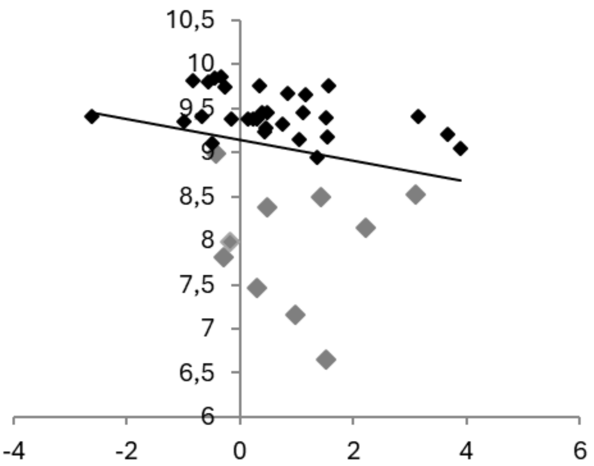

Figure 2. Relationship between geographical distance and trade flows

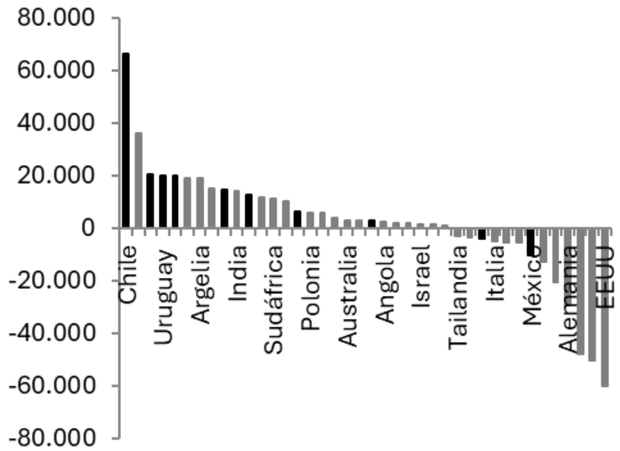

Figure 3. Relationship between trade balance and language

IV.Methodology and Results

Since the gravity equation is another widely used method in international economics to estimate trade elasticities, two versions of the gravity equation for Argentina are presented below: one applying pooled ordinary least squares (OLS) and another applying fixed effects (see Redding and Weinstein, 2019; Shepherd, Doytchinova, and Kravchenko, 2019).

The period is from the first quarter of 2004 to the fourth quarter of 2017, i.e., Q1 2004 to Q4 2017. The chosen countries are the most relevant to represent bilateral trade: Brazil, USA, China, and Chile. The following versions are proposed: trade flows, *Tij*, are the exports (*Xij*) and imports (*Mij*) of Argentina with these countries; *reerbij* is the bilateral real exchange rate; *gdpi* and *gdpj* are the respective incomes; *popi* and *popj* are populations; and *Distij* is the distance in kilometers between the countries. Formally (using pooled ordinary least squares - Pooled).

$$X_{ijt} = \beta_0 + \beta_1 gdp_{it} + \beta_2 gdp_{jt} + \beta_3 pop_{it} + \beta_4 pop_{jt} + \beta_5 d_{ijt} + \beta_6 reerb_{ijt} + u_{ijt} \quad (10)$$

$$M_{ijt} = \beta_0 + \beta_1 gdp_{it} + \beta_2 gdp_{jt} + \beta_3 pop_{it} + \beta_4 pop_{jt} + \beta_5 d_{ijt} + \beta_6 reerb_{ijt} + u_{ijt} \quad (11)$$

It is expected that *gdpi*, gdp*j*, and *reerbij* have positive signs for exports, while *Distij* is expected to have a negative sign. On the other hand, for imports, the same signs are expected, but *popi* is expected to have a negative sign. A version using panel data with fixed effects (FE) is also proposed.

Table 1 presents the results of estimating the gravity equation. It is observed that, taking either exports or imports as the dependent variable, the results are consistent with academic literature. Domestic income (gdpi) has a coefficient greater than 2 (higher in imports) and is statistically significant. The same applies for the trading partner's income (gdpj), with a higher elasticity in imports (although it is inelastic in the case of exports). These results validate the foundations of the model: trade flows are positively proportional to income. The bilateral real exchange rate has the correct sign in both models and is significant (and is inelastic as in country-level estimates).

Trade flows respond negatively to geographical distance[4] between countries, affecting imports more. Population-related variables are also statistically significant: in the case of domestic population (popi), an increase reduces exports, while the trading partner's population (popj) stimulates exports. The obtained results are consistent with estimates for Argentina (Jacobo, 2010). As usual, the goodness of fit is higher for imports than for exports, although both have relevant R2$R2$ values. Overall, import elasticities tend to be higher in all explanatory variables.

Table 2 presents an estimation using panel data with fixed effects (FE), controlling for country, to observe the differences with the previous results. Table 2 shows that the evidence using this methodology is not entirely satisfactory. The trading partner's GDP is not significant in exports, while the bilateral real exchange rate is also not significant in imports. This goes against economic theory and previous literature. Additionally, the local population variable is also not significant.

Table 1. (Pooled OLS)

LnX ij	Coefficients	Ln M ij	Coefficients
Ln GD¨Pi	2.303*** (0.375)	Ln GDPi	2.685*** (0.168)
Ln GDPj	0.606*** (0.041)	Ln GDPj	1.601*** (0.019)
Ln Reerbij	0.427*** (0.199)	Ln Reerbij	-0.153* (0.091)
Ln Popi	-8.392*** -1.927	Ln Popi	-13.583*** (0.772)
Ln Popj	1.657*** (0.120)	Ln Popj	4.709*** (0.057)
Ln distance ij	-8.442*** (0.621)	Ln distance ij	-23.087*** (0.295)
Observations	224	Observations	224
R2	0.684	R2	0.983

[4] In 1997, a book was published that contradicted this phenomenon. Frances Cairncross, in her book *The Death of Distance*, argued that the communications technology revolution would eliminate distance as a relevant variable for doing business. Some sectors of academia did not accept gravity models until recently because of the distance factor. For a discussion, see Head and Mayer (2013). Despite the exponential growth of communication technologies in recent decades, especially since 2000 with the rise of the Internet, empirical evidence continues to validate that greater distance corresponds to less trade (see Disdier and Head, 2008).

Table 2. (Fixed Effects)

Ln Xij	Coefficients	Ln Mij	Coefficients
Ln GDPi	3.018*** (0.419)	Ln GDPi	3.460*** (0.152)
Ln GDPj	-0.294 (0.209)	Ln GDPj	0.698*** (0.076)
Ln Reerbij	0.663*** (0.207)	Ln Reerbij	0.034 (0.075)
Ln Popi	4.983 -4.071	Ln Popi	1.556 -1.480
Ln Popj	-9.477** -3.845	Ln Popj	-9.031*** -1.398
Country Control	SI	Country Control	SI
Time Control	NO	Time Control	NO
Observations	224	Observations	224
R2	0.360	R2	0.927
N° Countries	4	N° Countries	4

V.CONCLUSIONS

Until the 1960s, academic interest in international trade elasticities was only related to the analysis of price and income effects noted by classical authors such as Orcutt, Johnson, and Houthakker. The traditional estimation method was regressions where the dependent variables were exports and imports, and the independent variables were income (domestic or from the rest of the world) and relative prices. However, starting in the 1970s, gravity models inspired by Tinbergen (1962) began to gain strength in empirical work.

This study estimated a gravity equation for Argentina and its four main trading partners—United States, China, Chile, and Brazil—from 2004 to 2017. The results align with the literature on the topic. Trade flows are positively related to domestic income and trading partner income, while inversely related to the geographic distance between countries. Like traditional elasticities, the gravity equations for imports recorded higher values compared to export elasticities. The pooled ordinary least squares model had a better fit than the panel model with fixed effects.

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