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The Impact of Logistics Performance on Argentina, Brazil, and the US Soybean Exports from 2012 to 2018: A Gravity Model Approach

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Abstract: Soybean is one of the main sources of protein directly and indirectly in human nutrition, and it is highly dependent on logistics to connect country growers and international markets. Although recent studies deal with the impact of logistics on international trade, this impact in agricultural commodities is still an open research question. Moreover, these studies usually do not consider the influence of all components of the logistics on trade. This paper, therefore, aims at identifying the role of logistics performance in soybean exports among Argentina, Brazil, the US and their trading partners from 2012 to 2018. Using an extended gravity model, we examine whether the indicators of the World Bank Logistics Performance Index (LPI), adopted as a proxy of logistics efficiency, are an important determinant of bilateral soybean trade facilitation. The results lead to the conclusion that it is necessary to analyze the LPI throughout its indicators because they may affect trade differently. The novelty of this article is to provide an analysis of the impact of different logistics aspects on commodity trade, more specifically in the soybean case. Finally, regarding the model results, logistics infrastructure has a positive and significant correlation with soybean trade as supposed in most of the literature.

Keywords: gravity model; soybean trade; agricultural commodities; logistics impacts on trade

1. Introduction

In today's global economy, logistics has been considered one of the key elements of international trade [1]. According to Christopher [2], logistics is the process of strategically managing the movement and storage of materials, parts, finished inventory, and the related information flows through the organizations and their marketing channels. Indeed, logistics allows countries to trade industrial and agriculture products all over the world. However, which aspects of logistics performance are more relevant when countries decide to negotiate is still an open research question.

Several studies have been addressing the logistics performance on international trade [1,3–10] using the Logistics Performance Index (LPI) of the World Bank [11] and connecting with basic elements of gravity models on trade [12–16]. Marti et al. [1], for instance, investigated the impact of LPI on trade in emerging countries with a maritime boundary. Bensassi et al. [6] established an augmented gravity model using the LPI and some local indicators to verify how geographical factors and transport infrastructure influence international competitiveness finding a connection between trade and logistics performance. Halaszovich and Kinra [9] analyzed the importance of the individual aspects of national transportation systems on trade patterns using the LPI in the Asian region. Moreover, Siddiqui and Vita [10] investigated the impact of logistics performance on trade concerning the garment sector in Cambodia, Bangladesh, and India employing panel data analysis and concluded that there is a significant impact of logistics on trade.

Originally, gravity models linked trade flows directly with economic size (gross domestic product (GDP)) and inversely with trade costs using geographical distance as an indicator of transportation [17]. Nevertheless, it is necessary to take in account that trade costs are large even considering free trade agreements and integrated economies, and cannot be reduced to distance effects only. According to Anderson and van Wincoop [18], trade costs include all transport, border-related, and local distribution costs from foreign producer to the final user in the domestic country, these trade costs are linked to the economic policy and related instruments (tariffs and trade barriers associated with the exchange rate systems), transport infrastructure investment, law enforcement and property rights, other regulations, and language. In this sense, logistics performance indicators can be used as a proxy to incorporate some of these aspects of trade costs in a gravity model.

Although several studies indicate a clear effect of logistics on trade, it remains unclear if the same effects are valid in the commodities supply chains. Actually, already some studies related to Brazilian soybean that argue that logistics infrastructure directly affects its trade [19], but they only consider transportation costs and port infrastructure to reach this conclusion. A comparison of the volume of soybean exports, for instance, reveals that the Brazilian volume in 2017 was 23% higher than that of the United States [20], even though the United States has superior logistics and lower cost of hinterland transportation for soybean and corn [21,22].

Agricultural products are essential for human life, and they are produced in high volumes and far from the consumer market. Moreover, they present unique particularities in comparison to industrial products that have not been tested. The soybean supply chain, for instance, presents singular characteristics such as a limited number of country growers, large consumers, and major food processing companies located in several countries. Agribusiness products present issues that are completely different from those concerning industrial products. These products, in general, are perishable during the most of the processing stage, and therefore require excellence in the logistics process. Soybean production demands storage, transport infrastructure, low freight costs, availability of different transport modes and routes, and efficiency in customs processes, factors measured by the LPI.

Based on these assumptions, we pose the following research questions in this paper.

RQ1: Does logistics performance influence the international soybean commodity trade?
RQ2: Which logistics aspects affect this trade?

To tackle these questions, we argue that logistics cannot be addressed in an augmented gravity model as a unique indicator using the main LPI index and—this is the way that it has usually been conducted in the literature. Given this understanding, it is necessary to verify how the different components of logistics performance behave on trade. Therefore, this paper considers the six indicators that compound the LPI index: infrastructure, customs, international shipments, logistics, quality and competence, tracking and tracing, and timeliness [11] to validate the logistics impact in a commodity supply chain, specifically for the case of soybean production.

The objective of this paper is to determine the impact of logistics performance, based on World Bank indicators, on soybean trade of Argentina, Brazil, and the US and their partners between 2012 and 2018. To do so, an augmented gravity model was established, and we applied panel data techniques using Pooled Ordinary Least Squares (OLS), Fixed Effects (FE), and Poisson Pseudo-Maximum Likelihood (PPML) estimators.

Our study contributes to the existing literature by analyzing the influence of different logistics performance factors over one of the most important global agricultural commodity trades and by providing a new insight of the use gravity models and statistical estimators in this sector.

The main results of this study confirm the importance of some logistics indicators on soybean trade. Among them, there is a positive and significant effect of the infrastructure of both importer and exporter countries, quality and competence, and tracking and trace of the importer. These results can help decision-makers in the development of policies related to agricultural logistics, considering the commodities marketing, mainly grains, as soybean and corn that share the same logistics channels.

The remainder of the paper is structured as follows. Section 2 reviews the literature concerning the agriculture and soybean market, trade, and logistics performance. Section 3 describes the augmented gravity model as our research methodology. Section 4 discusses the results obtained, and finally, Section 5 presents the conclusions of this study.

2. Literature Background

The literature background is divided into four subsections. First, we present the soybean supply chains with their characteristics, scenery, and volume of trade. In Section 2, we review several different approaches that authors use to deal with logistics performance in international trade on a broader scale. Moreover, we describe the use of gravity models adopted in some of those analyses. Section 3 conducts a review regarding the use of logistics performance indicators over soybean supply chain studies. In the end, Section 4 explains the World Bank Logistics Performance Indicator, poses some studies that use the LPI as a measure of logistics performance, and justifies our decision to use LPI in this study.

2.1. Soybean Supply Chains

Agriculture is essential to support human life. Therefore, there is much concern regarding food production. According to the United Nations, Department of Economic and Social Affairs, Population Division [23], the world's population is expected to reach 9.7 billion by 2050, boosting agricultural demand.

Nowadays, one of the main agricultural products commercialized overseas is soybeans. This grain is the world's richest and cheapest source of protein for animals and in the diets of people; it is also the second largest source of vegetable oil [24,25]. Since the 1990s, global demand for soybeans has increased by 145% worldwide, and it is projected to rise 70 to 80 million metric tons annually over the next 10 years [26]. In general, the seed contains 17% oil and 63% meal, 50% of which is protein [24,25].

Argentina, Brazil, and the US are major players in global soybean production; together, they were responsible for 80.5% of world production between 2012 and 2018 and 86.2% of exports between 2012 and 2017 [20]. Figure 1 shows the evolution of world, Argentina, Brazil, and the United States soybean production and exports for these periods.

Soybean is traded as a grain and two derivative products (soybean oil and soybean meal) obtained from pressing and separating soybeans through a process known as crushing [27]. Approximately 85% of the produced soybeans are crushed, wherein soybean meal is processed into animal feed, soy flour, and proteins, and soybean oil is refined into edible oil, fat acids, and biodiesel [28].

This market has huge significance for exporters. The Brazilian revenue for exports of this product in 2017/2018 was approximately US$ 25.7 billion, representing 13.75% of the country's GDP [29,30]. The soybean supply chain is presented in Figure 2.

Trading companies are the most important players in the soybean supply chain. They can intermediate the process of agricultural input acquisition and provide loans to local producers in return for soybean production. Trading companies are responsible for making the international commerce of soybean products possible. They operate in several markets, and four major trading companies correspond to 70% of the global trade: Archer Daniels Midland (ADM), Bunge, Cargill, and Louis Dreyfuss [28].

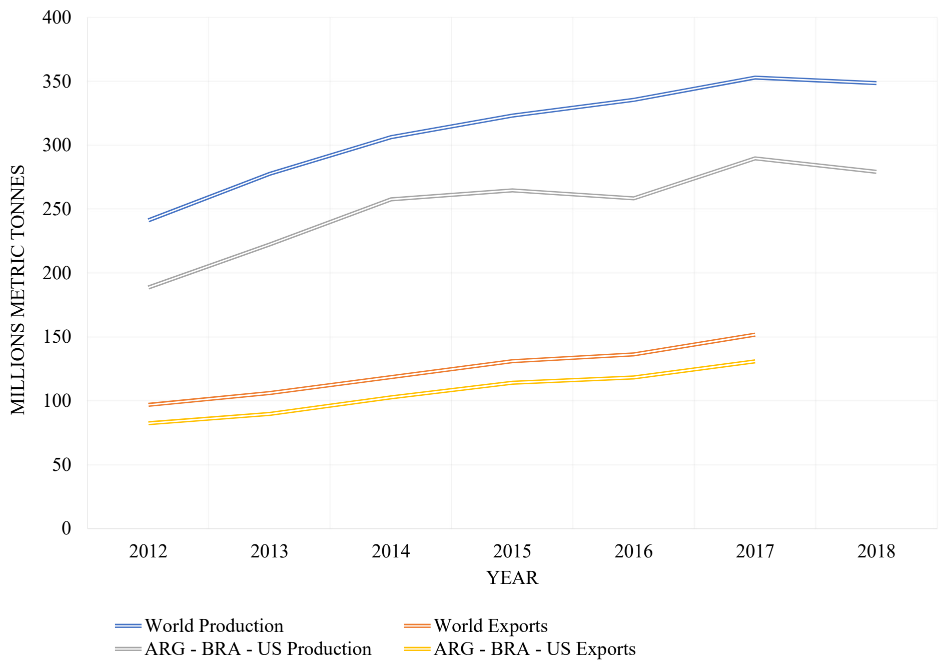

Figure 1. Volume of soybean production (2012–2018) and exports (2012–2016). Source: Adapted from FAOSTAT [20].

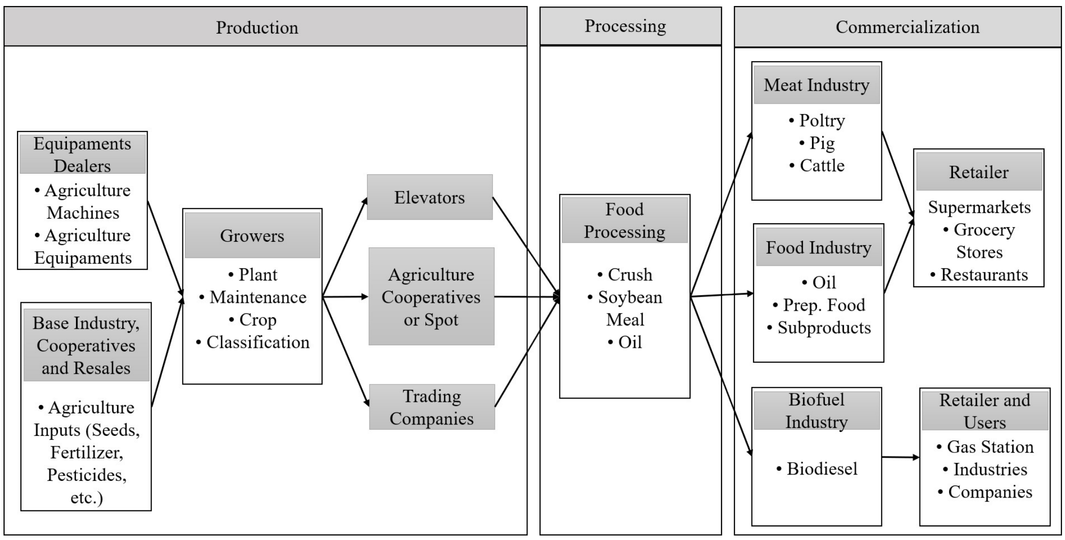

Figure 2. Soybean supply chain.

Growers can sell their production to trading companies, cooperatives, on the spot market, and to grain elevators. In the United States, growers prefer to sell to elevators to reduce costs of transportation between farms and cargo ports [31]. In Brazil, the transportation process is completely outsourced and managed by trading companies or elevators. Therefore, growers sell their soybean produce to traders or elevators that pick up the production directly from the farms. When selling to cooperatives, growers are responsible for the transport and storage of the production. In Argentina, growers use public elevators to export soybeans [32].

2.2. Trade and Logistics Performance

International trade depends on the capacity of the network that connects suppliers and markets at a reasonable cost. Therefore, trade logistics forms the backbone of international trade and encompasses freight transportation, warehousing, border clearance, payment systems, and many other functions [33].

Most literature regarding the relationship between logistics and international trade focus on aspects such as transportation costs, port efficiency, and infrastructure [34–37].

Limão and Venables [34] use three different datasets to analyze how transport depends on geography and infrastructure. They concluded that international trade is affected by infrastructure, and that a 50% reduction in transportation costs can improve trade by a factor of five. Sánchez et al. [35] also confirmed that international freight has an impact on trade, and that a reduction in transport costs directly stimulates exports and imports.

Regarding the influence of international trade on the logistics sector and vice versa, Nguyen and Tongzon [36] present the case of the trade relationship between Australia and China. They use an econometric analysis with multivariate models based on data regarding international trade, GDP, and outputs of the transport and logistics sectors between 1988 and 2006. Their results are unclear as to the direction. Nevertheless, the authors showed that the growth in Australia's trade with China led to the development of the Australian logistics sector but not the other way around.

Generally, the impact of logistics on international trade has been studied, focusing on maritime networks and service structures. Sánchez et al. [35] examine the determinants of marine transport costs and concluded that port efficiency is a relevant determinant of a country's competitiveness. In the same vein, Clark et al. [38] analyzed a database of more than 300,000 observations per year and found that port efficiency is an important determinant of shipping costs and bilateral trade. They found that increasing port efficiency from 25% to 75% reduced shipping costs by 12%. Márquez-Ramos et al. [39] investigate the relationship between maritime trade and maritime freight rates. They analyzed the effect of maritime networks, service structures, and port infrastructure on maritime rates, checking the endogeneity of the trade and freight rate variables and quantifying the impact of these factors on trade.

There are also studies that show that international trade is not only influenced by port efficiency, maritime rate, and transportation costs, but also internal logistics infrastructure. For example, Coşar and Demir [37] investigate how internal transportation infrastructure affects regional access to the international markets of Turkey. They confirmed that internal transportation infrastructure may play an important role in accessing international markets. Similarly, Reis and Leal [40] found that 60% of the logistics cost in Brazil involves internal transportation and warehousing, which directly affects the international trade of the country.

Despite studies that emphasize the importance of logistics on international trade, Bensassi et al. [6] affirm that econometric studies with gravity models focus only on the economic aspects of trade such as GDP and FTAs. Tinbergen [12], Anderson [13], Bergstrand [14,15], Deardorff [16], Anderson and van Wincoop [18], Head and Mayer [41], and Shepherd [17] provided more details regarding gravity models in international trade.

It is important to note that a typical international shipment requires both international and domestic transportation, with a possible trans-shipment across different modes at a harbor, an airport, or a border crossing. However, gravity equation models typically consider only the distances between the main cities of the involved countries [18,37].

Meanwhile, some authors such as Castaño et al. [42] and Ekici et al. [33] analyze the performance of logistics on international trade as a whole. Castaño et al. [42] investigate the impact of logistics performance on international trade flows in two contexts: hardware and software indicators. Hardware indicators represent overland and maritime infrastructure endowments, and software indicators represent different management performances in different countries. They found that logistics helps to improve and maintain the level of competitiveness of the two countries. According to Ekici et al. [33], a country's ability to trade globally depends upon trader's access to efficient logistics. They argued that there is a close relationship between global competitiveness and logistics efficiency. Table 1 summarizes the main articles regarding logistics performance and trade.

Table 1. Summary of studies that analyze the effect of logistics performance on trade.

Study	Focus	Techniques	Measures
Bensassi et al. [6]	To simultaneously analyze domestic Spanish and foreign trade and estimate the empirical relationship between logistics and trade	Augmented gravity model	World Bank LPI and Local LPI developed by the authors
Clark et al. [38]	To explore the factors affecting port efficiency and the effect of port efficiency on transport costs	Price equations	Port efficiency is ranked on a one-to-seven index based on surveys performed in representative firms of each country
Castaño et al. [42]	To investigate the effects of logistic performance on international trade flows	Augmented gravity model	Hardware (ports and roadways infrastructure), software (technology and human capital), and logistics variables developed by the authors
Coşar and Demir [37]	To understand how internal transportation infrastructure affects regional access to international markets	Elasticity equations of distance and trade associated	Road network data in Turkey
Ekici et al. [33]	To develop a decision making tool to support policy makers in improving the logistics performance of their country	Fuzzy linguistic and artificial neural networks in a case study	World Bank LPI
Hilmola [43]	To identify through proposed data envelopment analysis (DEA) models, oil exporters with the most potential to develop further	DEA models	World Bank LPI
Limão and Venables [34]	To study the determinants of transport costs and how they depend both on countries' geography and their infrastructure levels	Gravity models	Levels of infrastructure (measured by an index combining road, rail, and telecommunications density)
Marques-Ramos et al. [39]	To investigate the relationship between maritime trade and maritime freight rates at sectoral level	Price equations	Transportation freight rates
Nguyen and Tongzon [36]	To examine the dynamics of the causal relationship between trade and transport sector, especially in the context of Australia's trade with China and the Australian transport and logistics sector	Gravity models; test was conducted using equation with lag length being selected using the Akaike information criterion (AIC) and the Schwartz Bayesian criterion (SBC)	Growth rate of the transport and logistics sector
Reis and Leal [40]	To develop a new mathematical model that operates from the point of view of a single shipper to plan the logistics for a soybean supply chain	Linear programming model	Revenue soybean value and cost of transportation
Sánchez et al. [35]	To examine the determinants of maritime transport costs with particular emphasis on efficiency at the port level	Principal Component Analysis	Maritime transport cost
Shepherd and Hamanaka [44]	To identify major challenges that Asian–Pacific policy-makers face in drawing up international logistics policies, and to seek possible solutions to problems	Multiple case studies	World Bank LPI, Corridor performance measurement and monitoring (CPMM) and Maputo corridor logistics initiative (MCLI)

2.3. Logistics Performance on Soybean Trade

In the agribusiness sector, there is a lot of discussion among stakeholders regarding the influence of logistics performance on agricultural trade. In soybean production, for example, there is a common sense among farmers, trading companies, logistics operators, governments, and so on that logistics is responsible for the main costs alongside the supply chain. With this in mind, organizations and scholars are investigating the role of logistics on soybean trade to confirm or contradict this belief.

Salin [21] of the United States Department of Agriculture shows a huge difference between Brazilian and North American transportation costs. However, between the 2015/2016 year crop and the forecasting of the 2019/2020 year crop Brazil's exports of the soybean in grains will be predicted to increase 39% exports against a reduction of 3.5% of the United States in the same period. The data suggest a low correlation between logistics performance and soybean trade. However, it is essential to emphasize that between 2017 and 2018 occurred a commercial trade war between the US and China and soybean supply chains were very affected what may have been influenced this result.

As mentioned previously, the soybean is traded as grain, oil, and meal. Reis et al. [45], studying the topic, concluded that maritime transportation of soybean grains is cheaper in comparison to oil or soybean meal, indicating a reason for the greater number of grain trade. Moreover, the authors realized that maritime freight was almost the same among Argentina, Brazil, and the United States exports to China, trade prices are based on the Chicago Trade Board, and exports use Free On Board (FOB) incoterm. These observations indicate that hinterland logistics perhaps has a low influence on the soybean trade market.

On the other hand, Toloi [46] provides a different explanation regarding the influence of logistics on soybean trade. The author investigating the prices of soybean grain in Mato Grosso state, responsible for almost 30% of Brazilian production, found that prices paid by trading companies on the production site are at large 30% less than the Chicago Trade Board. This striking difference could represent the impact of logistics performance on trade.

South American countries keep striving to reduce the impact of their poor internal logistics performance to obtain improved profitability. Lopes et al. [47] indicate that Brazil, even with lower production costs, has a low competitive advantage due to difficulties with product distribution caused by problems in the logistical network. Lima et al. [19], studying the impact of the variation in export volumes of soybean to China on the Brazilian port infrastructure, suggest that to reduce the bullwhip effects provoked by the Midwest Producer States it is necessary to design informational and coordination mechanisms to integrate the logistical agents involved in the export process and to invest on infrastructure (storage capacity).

Another typical aspect experienced by South American countries is the conditions for freight transportation. Danao et al. [48] explain that in Brazil, over 60% of soybeans are transported by truck from farms to processing, storage, and export terminals, and poor road conditions, improper truck maintenance, overloading, and inefficient transfer of grain are major causes of transportation losses. This is an important aspect when dealing with agricultural commodities.

Melo et al. [49] measure and compare the efficiency of Brazilian and American soybean transport corridors, from farmers to export ports, using data envelopment analysis (DEA). The findings indicated that efficient routes and corridors tend to present short-distance truck trips and long-distance train or barge trips. The efficiency of the inland waterway trips depends on how many barges are used in the same expedition. Routes with more than three modes tend to be inefficient, which suggests that there is a limit for multimodality.

With these ideas in mind, the present study seeks to capture the impact of the logistics performance on soybean trade using an augmented gravity model to confirm or refuse some of these findings in the literature. Table 2 summarizes the main articles regarding logistics performance on soybean trade.

Table 2. Summary of studies that analyze the effect of logistics performance on soybean trade.

Study	Focus	Techniques	Measures
Danao et al. [48]	It describes the design, fabrication, and testing of custom instrumentation for recording grain conditions (using soybeans) and logistics during short-haul truck transport from farms to storage	Sensors analysis	Data about humidity and CO_2 emissions of grains during the transportation using datalog and GPS
Lima et al. [19]	It aims to identify the impact of the variation in export volumes of soybean to China on the Brazilian port infrastructure, exploiting the concept of the "bullwhip" effect (BE)	Bullwhip Effect calculation	Data on the export volumes of the five largest Brazilian soybean-producing States
Lopes et al. [47]	It seeks to aid in strategic transport decision-making to soybean via a discrete event simulation project	Simulation	Route costs and availability of ports
Melo et al. [49]	It purposes to collectively measure and compare the efficiency of Brazilian and American soybean transport corridors, from farmers to export ports	Data Envelopment Analysis (DEA) and Principal Component Analysis (PCA)	Data and cost for selected routes
Reis et al. [22]	It investigates the soybean supply chains and compare the maritime transportation costs among soybean products: grain, meal, and oil	Social Network Analysis and Price equations	Maritime transport cost and soybean products volume
Salin [21]	It studies the costs of soybean transportation in Brazil and the US to Main Markets infrastructure levels	Price comparison	Road, Train, and Maritime freight rates
Toloi [46]	It analyzes the factors that affect soybean production, commercialization, and logistics	Interviews and Analytic Hierarchy Process	Field research with producers and specialists

2.4. Logistics Performance Index

Logistics performance is highly important to international trade. As a example, according to Clark et al. [38], a 10 percent increase in supply chain uncertainty reduces imports by 1 to 2% and it is connected with shipment delays.

The World Bank presents the main studies on global logistics performance. The LPI is a guide published every two years since 2007 (the period between the first and second editions was three years). It assesses logistics performance as a whole for more than 160 countries. The LPI index assesses logistics performance along six indicators [11]:

- Customs: the efficiency of customs and border clearance.
- Infrastructure: the quality of trade and transport infrastructure.
- Logistics, quality and competence: the competence and quality of logistics services (trucking, forwarding, and customs brokerage).
- Timeliness: the frequency at which shipments reach consignees within scheduled or expected delivery times.
- International shipments: the ease of arranging competitively priced shipments.
- Tracking and trace: the ability to track and trace consignments.

The LPI index comprises a survey with a standardized questionnaire having two sections: international and domestic. The respondents assess the six key areas and provide qualitative and quantitative data regarding the logistics environment of the country in which they operate. In 2018, for instance, almost 6000 assessments were made by logistics professionals. The scores are calculated using a scale between 1 and 5, where 5 is the maximum level of logistic efficiency [11]

The LPI has been used in several studies to answer questions related to logistics performance and trade [1,3–7,9,43,44]. Hilmola [43] examine the top 20 oil exporters and their efficiency using the LPI as an indicator of economic prosperity. The results indicated that logistics performance and competence are the key factors that enable increased diversification of import–export performance and should be the primary development objective of prosperous oil economies.

Shepherd and Hamanaka [44] examine the challenges facing trade logistics using the LPI index and Asian–Pacific experiences. They revealed that the LPI is not without its flaws, but as the surveyed firms are logistics providers, they are able to represent the voice of the logistics providers' community.

Marti et al. [1] analyze the trade flows in emerging nations with a maritime boundary applying gravity models adopting LPI as a proxy of trade facilitation and identified the influential of the logistics indicator on trade in Middle East exporters. Furthermore, Marti et al. [3] use the LPI to analyze differences between countries in terms of customs procedures, logistics costs, and the quality of the infrastructure for overland and maritime transport. The results confirmed that improvements in any of the components of the LPI can lead to significant growth in a country's trade flows.

Puertas et al. [4] indicate that logistics performance has become a decisive factor in export competitiveness. They studied the importance of logistics performance in regard to EU exports using several gravity equations and the LPI. They concluded that logistics was more important for exporting nations than importing ones.

Saslavasky and Shepherd [5] adopt the LPI to identify that networked trade in parts and components is more sensitive to the importer's logistics performance than the final goods trade. They also found that logistics performance is important for trade among developing countries in the Asia-Pacific region.

Bensassi et al. [6] utilize the LPI to develop an augmented gravity trade model that specifically includes logistics and transport infrastructure as explanatory variables. They used data regarding the bilateral exports of 19 Spanish regions and found that logistics is indeed important for the analysis of international trade flows.

Gani [7] concluded that the continuous growth in world trade depends on the efficiency of the logistics services. To do so, he explores the effect of logistics performance in international trade estimating standard export and import equations incorporating measures of logistics performance, specifically the LPI.

Halaszovicha and Kinra [9] studied the importance of the individual aspects of national transportation systems on trade patterns in the Asian region and found the elements of national transportation systems positively influence trade. To do so, they used the dimensions of World Bank LPI.

Although these studies utilized the LPI to analyze international trade, they usually address it using the LPI as a whole without considering the impact of its indicators. Moreover, none of them considered the nature of agricultural products. Agricultural products have a low price, high volume, and are produced in specific areas of the world depending on soil availability and quality, climate characteristics, and the availability of natural resources.

In this article, we tested the logistics performance on soybean trade of Argentina, Brazil, the US, and their partners using the six indicators that compound the LPI. Our hypothesis is these indicators influence differently on soybean trade. The LPI was used in our study for its abrangency that allowed us to establish a pattern for logistics indicators over all the countries presents in the study.

Finally, despite the fact that the World Bank provides the LPI every two years, it is consolidated in an aggregate LPI. This aggregate LPI combines the four recent LPI editions scoring the six indicators across 2012/2014/2016 and 2018 creating a big picture to better indicates the logistics performance of the countries [11]. The advantage of this approach is reducing the random variation of one survey to another and comparing 167 countries without missing values. The aggregate LPI was adopted in this study.

3. Material and Methods

To explore the influence of logistics on soybean trade, we utilized an augmented gravity model. This model is based on the gravity equation that is used to explain international trade [12–17,41,50]. Generally, the gravity equation model is represented by Equation (1) [51]:

$$X_{ij} = GS_i M_j \theta_{ij} \tag{1}$$

where X_{ij} the volume of exports between pairs of countries: exporter i and importer j; G is the constant variable that is not dependent on i or j; S_i represents factors related to exports such as the exporter's GDP; M_j represents factors related to imports such as the importer's GDP; and θ_{ij} links to exporter i's ease of access to the import market j.

The augmented gravity model expands the set of variables used to explain relationships in the standard gravity model [5,6]. Several additional variables are adopted to establish bilateral relations between countries [41]. The advantage of this model is that it allows new variables that explain the commercial relations between country i and j to be incorporated [6].

As the original model and the nature of data, which involve monetary values and large-measure units (e.g., kilometers), are nonlinear, it is necessary to perform a log-linear regression as indicated for Baier and Bergstrand [52], resulting in the following model.

$$lnX_{ij} = lnG + lnS_i + \gamma lnM_j + \sum_k \delta_k A_{ij} + \epsilon_{ij} \tag{2}$$

A log-linear regression can be estimated using ordinary least square regression, which is easier to solve using nonlinear estimation methods [51]. The term $\sum_k \delta_k A_{ij}$ represents bilateral variables that hinder or facilitate trade, such as distance, transport costs, and other dummy variables [6]. For example, these variables can represent a common border or language between partners.

Despite the fact that gravity models and augmented gravity models have been used with LPI in literature [1,3–7,9], our study is the first to identify logistics performance influence in international soybean trade based on logistics indicators that compose the general LPI index of the World Bank [11]. According to Martinez-Zarzoso and Nowak-Lehmann [53], an augmented gravity model is used to extend trade costs beyond the distance including new explanatory variables such as transport infrastructure. Therefore, we decided to adopt the method.

Anderson and van Wincoop [54] grounded theoretically that a gravity model needs to consider the resistance of trade, where intuitively the more resistant to trade with all others a region is, the more it is pushed to trade with a given bilateral partner, this effect is called multilateral resistance. Bensassi et al. [6] explain that a gravity model can use exporter and importer fixed effects or exporter-time and importer-time fixed effects in panel data applications to tackle MRT. However, Baier and Bergstrand [52] infer that fixed effects estimation cannot retrieve the multilateral price terms necessary to generate quantitative comparative-static effects without also employing the structural system of equations and suggest an alternative OLS log-linear specification that introduces a theoretically motivated exogenous MRT.

Due to the limitation to tackle MRT using a time-invariant variable in the model such as the LPI, we decided to consider the logistics variables as one way to study trade costs beyond the distance between countries i and j. However, despite the fact the article does not cope with all MRT aspects, this does not invalidate the results [6,52,55].

In this particular context, we considered the period 2012–2018 of soybean exports from Argentina, Brazil, and the US, together with basic terms of gravity model and logistics performance indicators of the World Bank developing an augmented gravity model that is specified in Equation (3).

$$\begin{aligned} lnX_{ijt} = \gamma_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{jt} + \beta_3 lnD_{ij} + \beta_4 Cust_i + \beta_5 Cust_j + \beta_6 Infra_i + \beta_7 Infra_j \\ +\beta_8 Ship_i + \beta_9 Ship_j + \beta_{10} LQC_i + \beta_{11} LQC_j + \beta_{12} TT_i + \beta_{13} TT_j + \beta_{14} Tim_i + \beta_{15} Tim_j + \beta_{16} Lang_{ij} \\ +\beta_{17} Bor_{ij} + \beta_{18} FTA_{ij} + \tau_t + \delta_{ij} + \epsilon_{ijt} \end{aligned} \quad (3)$$

where lnX_{ijt} represents the logarithm of soybean exports between country i to j over time t. As it is usual in gravity equations, the $lnGDP_{it}$ corresponds to the logarithm of the exporter's GDP in year t, and $lnGDP_{jt}$ is the importer's GDP in year t. The variable lnD_{ij} refers to the logarithm of the distance between major or relevant ports for soybean trade in both countries. The logistics performance index is divided in six indicators: customs ($Cust$); infrastructure ($Infra$); international shipments ($Ship$); logistics, quality, and competence (LQC); tracking and tracing (TT); and timeliness (Tim). Note that all these variables are linked to exporter i or exporter j individually. Finally, as is common in gravity equations, a dummy variable is an artificial variable created to represent an attribute with two or more distinct categories/levels used in regression analyses [56]. We included three dummy variables in the equation: common language ($Lang$), common border (Bor), and free trade agreement (FTA), where 1 corresponds to the existence of a relationship between countries, and 0 otherwise. Finally, we control unobserved heterogeneity and collinearity among variables using bilateral effects (δ_{ij}) and time-fixed effects (τ_t) year. [6,57].

We adopted this model specification to run the panel data techniques. After that, following the concepts established by Silva and Tenreyro [58] and Montant [59], we applied one variant based on Poisson Pseudo-Maximum Likelihood (PPML) where exports do not have applied the logarithm (Equation (4)).

$$\begin{aligned} X_{ijt} = \gamma_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{jt} + \beta_3 lnD_{ij} + \beta_4 Cust_i + \beta_5 Cust_j + \beta_6 Infra_i + \beta_7 Infra_j \\ +\beta_8 Ship_i + \beta_9 Ship_j + \beta_{10} LQC_i + \beta_{11} LQC_j + \beta_{12} TT_i + \beta_{13} TT_j + \beta_{14} Tim_i + \beta_{15} Tim_j + \beta_{16} Lang_{ij} \\ +\beta_{17} Bor_{ij} + \beta_{18} FTA_{ij} + \tau_t + \delta_{ij} + \epsilon_{ijt} \end{aligned} \quad (4)$$

The goal of this second model is to compare the initial results with the PPML, an alternative estimator for gravity models [17] that leads to robust estimates even if there is heteroskedasticity and it is not based on the logarithm of trade but on its level [59,60], creating a second check for FE results.

Data

To determine whether logistics factors affect soybean trade, a balanced panel database was consolidated according to gravity models theory including gross domestic product, distance between countries of the trade, dummies variables regarding common language, common border, free trade agreement, and logistics performance index indicators originated from different statistical sources. Details for each variable considered in our empirical analysis are presented in Table A1 in the Appendix A.

The regression models were performed using Stata MP ©software version 16 (StataCorp LLC, College Station, TX, USA). The descriptive statistics of variables adopted are summarized in Table 3.

Table 3. Descriptive statistics.

Variable		Obs	Mean	Std.Dev.	Min	Max
Bilateral exports	*X_ijt*	1092	7.05×10^8	4.16×10^9	0	6.86×10^{10}
Log of bilateral exports	*lnX_ijt*	789	17.33	3.54	2.08	24.95
Log of GDP exporter	*lnGDP_it*	1092	28.98	1.42	26.98	30.65
Log of GDP importer	*lnGDP_jt*	1092	26.39	1.64	20.93	30.65
Log of distance	*lnD_ij*	1092	9.22	0.66	6.80	10.00
Common language	*Lang_ij*	1092	0.22	0.41	0	1
Common border	*Bor_ij*	1092	0.08	0.28	0	1
Free Trade Agreement	*FTA_ij*	1092	0.19	0.39	0	1
Customs of exporter	*Cust_i*	1092	3.04	0.62	2.49	3.76
Customs of importer	*Cust_j*	1092	2.90	0.59	1.79	4.09
Infrastructure of exporter	*Infra_i*	1092	3.42	0.59	2.81	4.10
Infrastructure of importer	*Infra_j*	1092	3.04	0.67	1.83	4.38
International shipments of exporter	*Ship_i*	1092	3.17	0.32	2.89	3.54
International shipments of importer	*Ship_j*	1092	3.09	0.46	2.18	3.97
Logistics, quality, and competence of exporter	*LQC_i*	1092	3.39	0.48	2.82	3.93
Logistics, quality, and competence of importer	*LQC_j*	1092	3.10	0.59	2.02	4.26
Tracking and tracing of exporter	*TT_i*	1092	3.57	0.48	3.13	4.13
Tracking and tracing of importer	*TT_j*	1092	3.17	0.59	1.76	4.22
Timeliness of exporter	*Tim_i*	1092	3.74	0.34	3.41	4.14
Timeliness of importer	*Tim_j*	1092	3.50	0.53	2.46	4.40

4. Results and Discussion

4.1. Main Results

The main purpose of this work is to test the impact of logistics performance on the bilateral soybean exports from Argentina, Brazil, and the US and their partners using data over the period 2012–2018. The indicators of the LPI were incorporated to the augmented gravity model as a proxy of logistics efficiency. Regression results for the estimated gravity model are summarized in Table 4.

Panel data were used because it has several advantages over cross section analysis due to the capture of the relationships between the relevant variables over a longer period and because it is able to disentangle the time-invariant country-specific effects [61]. Panel data can be estimated using pooled ordinary least square (OLS), fixed effects (FE), and random effects (RE) estimators [62].

Pooled OLS (column one) is a multilinear regression model with panel data based on assumptions of linearity, exogeneity, homoscedasticity, non-autocorrelation, and full rank [63]. Moreover, the individual effects are fixed and common across all cross section units of Pooled OLS, where there is a problem of endogeneity because the estimate is biased due to unobserved heterogeneity. However, compared with the cross-sectional OLS, the bias is less [63].

The results obtained in Pooled OLS show that two logistics variables are positively correlated to trade: infrastructure ($Infra_j$) and logistics, quality and competence (LQC_j) of importer. These results suggest that soybean flows in the direction of more efficient corridors to deliver the product to the final customer.

Table 4. Gravity estimates for soybean exports from Argentina, Brazil, and the US using different estimators.

Variable	*OLS*	*FEM*	*PPML*
lnGDP_it	0.335 (0.764)	1.797 ** (0.795)	−0.735 (0.480)
lnGDP_jt	0.605 * (0.330)	−1.222 (0.914)	−0.475 (0.541)
lnD_ij	1.615 *** (0.571)	10.345 *** (0.653)	5.651 *** (0.349)
Bor_ij	0.002 (0.926)	26.792 *** (0.829)	14.626 *** (0.354)
Lang_ij	1.871** (0.727)	1.842 *** (0.208)	−0.195 *** (0.062)
FTA_ij	0.390 (0.596)	0.393 (0.257)	1.843 *** (0.086)
Cust_j	−5.103 ** (2.560)	−12.984 * (7.243)	−6.637 (4.359)
Infra_j	1.928 * (2.283)	13.227 *** (3.462)	3.455 * (2.057)
Ship_j	0.696 (1.778)	−43.298 *** (6.177)	−20.604 *** (3.690)
LQC_j	5.110 *** (2.867)	28.090 ** (12.178)	12.835 * (7.338)
TT_j	−5.493 ** (2.405)	38.776 *** (3.340)	37.151 *** (2.150)
Tim_j	2.831 (1.982)	−41.362 *** (1.427)	−34.646*** (0.819)
Cust_i	−2.192 (2.533)	−44.402 *** (7.920)	−43.877 *** (4.084)
Infra_i		45.149 *** (9.847)	50.092 *** (4.860)
Ship_i			
LQC_i	2.851 (5.491)		
TT_i			
Tim_i			
Cons	−28.401 (18.967)	−57.233 * (33.950)	−3.781 (24.297)
Obs.	789	789	1091
Adj R2	0.245	0.776	0.971
Hausman test *p*-values		0.000	
Time test effect		0.001	
Breusch-Pagan test *p*-values	0.000		

Note: Robust standard errors in brackets; OLS denotes Pooled Ordinary Least Squares, FE denotes fixed effects, and PPML denotes Poisson Pseudo-Maximum Likelihood; * Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level; Variables without coefficient are dropped due to collinearity.

Concerning the control variables, GDP of the importer, common language, and distance have a positive and significant coefficient. In the gravity model literature, GDP and language are positive to trade, but are expected to have a negative sign to distance [17,64]. Nevertheless, it is important to highlight that our study considered the three main soybean exporters of the world and they are located in the American continent, while the most of importers are established in Europe and Asia, far from the origin, see Figure 3.

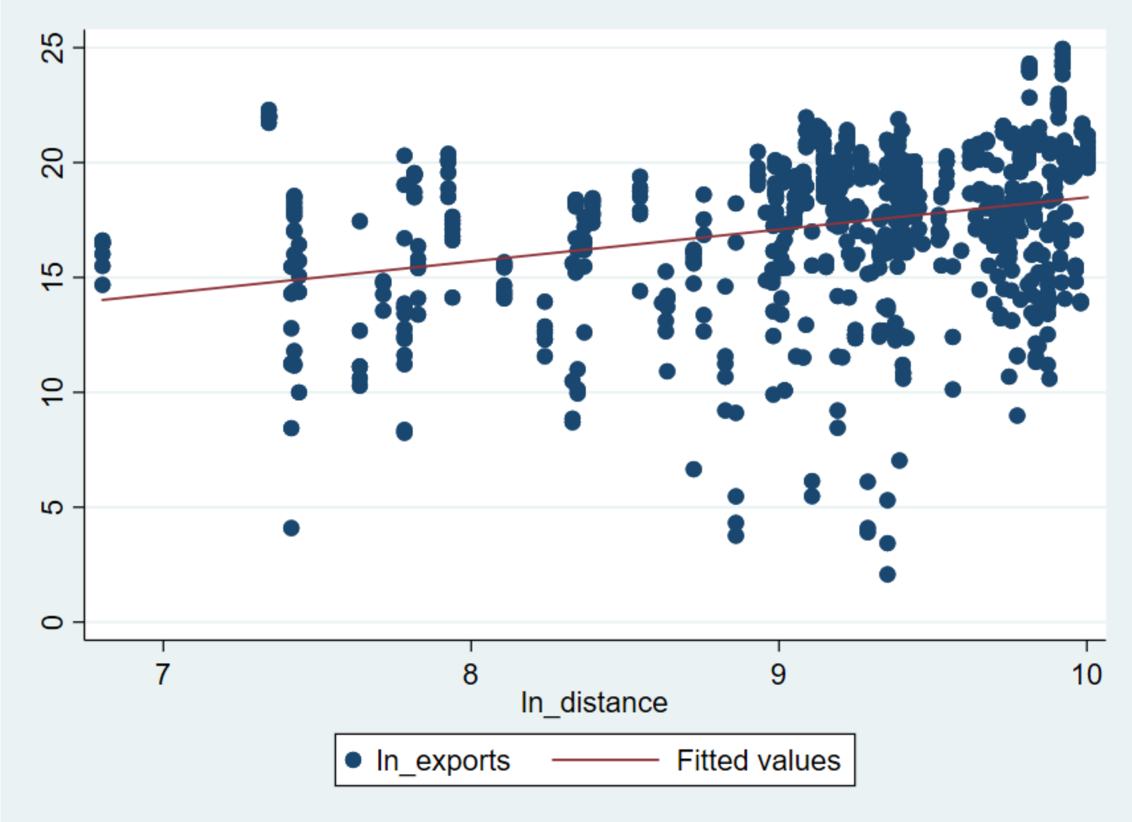

Figure 3. Relation between exports and distance.

The positive impact of distance on soybean trade can be explained by the developing of transportation systems. A developed transportation system allows large quantities of goods to be moved, the adoption of a low-cost production location, and have a cheap transportation model for low-margin products [9]. At the same direction, Saslavsky and Shepherd [5] attribute the allocation of supply chains and production processes across multiple countries based on lower transportation costs, better and cheaper access to communication technologies, and even the reduction of tariffs. As an example of the low soybean transportation costs, the movement of one metric tonne from Argentina, Brazil, and the US to China costs approximately US$ 50.00 [21].

Finally, the common language has an impact on soybean trade and confirms the colonial effects [17,59]. Many countries have Spanish and English as the main idioms indicating the cultural and historical presence in this trade. According to Dadakas et al. [65], common language reflects similarities in habits and culture.

The OLS provided a R^2 of 0.245, which means that the explanatory variables account for approximately 24 percent of the observed variation on soybean trade. However, it is important to infer that the OLS estimator based on panel data is no longer the best unbiased and linear estimator, due to endogeneity results in biased regression estimates that appear because of unobserved heterogeneity presents in real-life data [63].

Therefore, we decided to run the Breusch and Pagan LM tests to compare between the two panel techniques: pooled OLS or RE. The null hypothesis in the LM test was that variances across entities are zero, and there is no significant difference across units [57,66]. The LM statistic (p-value 0.000) rejects the null hypothesis and thus it is necessary to adopt random effects regression. However, before dealing with random effects, we decided to perform the Hausman test to compare FE with RE models to verify which model fits properly for our data. Our null hypothesis was that the unique errors (u_i) are not correlated with the regressors [57,61,63,66]. The hypothesis was rejected (p-value 0.000), indicating that FE is preferred to RE. Finally, a test for time-fixed effects was applied where the null hypothesis verifies the coefficients for all years are jointly equal to zero [67]. We rejected the hypothesis (p-value 0.001) showing the necessity of address time fixed effects.

Furthermore, note that one way to restore homogeneity and to solve the endogeneity problem is to decompose the random error in cross section-specific or time-specific (one-way error component model) or both cross section- and time-specific (two-way error component model) and solving using FE or RE [63]. It is feasible to assume that something within the individual may impact or bias the predictor or outcome variables and we need to control for this using FE [57,68,69].

Column two presents the results obtained using the fixed effect model; we included fixed effects for country-pair (grouping importer and exporter) and year. The FE results show the GDP of the importer as positively significant, confirming the assumption that soybean trade could be linked to the cultural effects more than economic ones. The model was highly consistent presenting a high R^2 level (0.776). Besides that, the FE model indicates that infrastructure ($Infra$) has an important role on soybean trade where an increase of one unit for importer infrastructure represents a rise of 13.227 on trade or 45.149 in case the increase occurred in the exporter infrastructure. Moreover, the FE approach confirms that tracking and trace (TT_j) and logistic quality and competence (LQC_j) of the importer are positively correlated to soybean trade. According to Puertas et al. [4], infrastructure and competence are closely linked to the public policies indicating a direction to be followed for trade partners in soybean supply chains.

Considering the control variables of trade, GDP of the importer is positively significant to trade as expected [17] and distance showed the same behavior of OLS estimation. However, in this model, sharing a common border or a common language is positively significant at the 1% level

Finally, in column three the Poisson Pseudo-Maximum Likelihood (PPML) model is estimated as an alternative to OLS and FE effects. According to Shepherd [17], the PPML is consistent in the presence of fixed effects, including the observations of zero trade value, and the interpretation of the coefficients from the Poisson model follows exactly the same pattern as under OLS.

The results obtained using this alternative method were somewhat equivalent with the FE model. The logistics indicators remain almost unchanged except for the coefficients and some significance level. The main differences are in the basic elements of gravity models as GDP, where both are not related to soybean trade, and common language presented a negative sign. The result may be related to the fact that the PPML does not exclude bilateral observations with zero trade as in the log transformation [58,59] capturing properly the great presence of China on the soybean market. The PPML model presents a high R^2 level (0.971).

As can be seen in the literature, logistics performance impacts the trade, such as presented in the studies of Saslavsky and Shepherd [5] regarding parts, components, and final goods; in Bensassi et al. [6] considering Spanish region exports; in Marti et al. [1] studying five emerging geographical regions which have a maritime boundary; and Gani [7] investigating international trade using 60 countries. However, our results show that it is necessary to consider not only LPI as a whole, but all the LPI indicators that may report different impacts on trade, allowing decision-makers to create specific policies to tackle specific logistics indicators that are more able to increase trade.

4.2. Robustness Checks

Two robustness checks were conducted in this study. First, we included a measure of geographical country size for importers and exporters to analyze the impact of hinterland logistics. Second, we verify if the US/Chinese trade war impacted the soybean trade by removing the years of 2017 and 2018 where the war trade started to occur. The results can be seen in Table 5.

The first robustness check consists in including geographical area as a variable in the model as an attempt to verify the impact of internal logistics in soybean trade. Both country sizes were positive and significant to trade. However, the infrastructure of exporter was dropped due to collinearity [17], suggesting a relation between country size and infrastructure. This fact was only noted for the exporters, maybe due to the low number. Nevertheless, this result does not affect the conclusion of the Table 4 that infrastructure affects soybean trade.

Regarding the US/Chinese trade war, we intended to check whether it has a significant impact on the soybean trade that affects the role of logistics performance indicators. The analysis presented in the second column of Table 5 indicates a variation on coefficients; nevertheless, the significance of the variables remains the same, confirming the impact of some LPIs on soybean trade.

Table 5. Robustness checks.

Variable	FEM (Geographic Area)	FEM (Without Trade War)
lnGDP_it	1.797 * (0.794)	1.809 * (1.010)
lnGDP_jt	−1.123 (0.914)	−1.709 (1.205)
lnD_ij	7.820 *** (1.320)	8.805 *** (0.916)
lnSize_i	3.443 * (2.006)	
LnSize_j	2.774 *** (0.781)	
Lang_ij	1.842 *** (0.208)	1.836 *** (0.225)
Bor_ij	15.110 *** (2.769)	24.750 *** (0.936)
FTA_ij	0.393 (0.257)	0.345 (0.276)
Cust_j	16.954 *** (1.201)	−19.761 ** (9.636)
Infra_j	2.621 *** (0.607)	16.390 *** (4.817)
Ship_j	−20.782*** (0.384)	−52.198 *** (8.591)
LQC_j	−5.446 * (2.790)	43.388 *** (16.179)
TT_j	30.284 *** (5.594)	25.089 *** (4.821)
Tim_j	−33.446*** (3.130)	−30.320 *** (2.097)
Cust_i	−3.943 *** (1.308)	−30.518 *** (9.406)
Infra_i		29.804*** (11.364)
Ship_i		
LQC_i		
TT_i		
Tim_i		
Cons	−109.758 (45.388)	−22.326 (38.945)
Obs.	789	572
Adj R2	0.776	0.814

Note: Robust standard errors in brackets; FEM (bilateral trade) denotes importer and exporter time effects considered separately, and both LPI are summed (exporter and importer); FEM geographic area denotes fixed effects of countrypair and year and include ln of exporter and importer country size; and FEM without trade war denotes that 2017/2018 are dropped to avoid the US and China trade war; * Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level; Variables without coefficient are dropped due to collinearity or not included in the sensitivity model.

5. Conclusions

This study analyzed the effects of logistics performance on soybean trade. We rely on soybean exports of the three major exporters (86.2%): Argentina, Brazil, and the US between 2012 and 2018. We studied this trade using a framework that comprises a gravity model augmented with common variables of trade, such as GDP, distance, and logistics indicators (logistics performance index provided by the World Bank).

Our results reveal the importance of the consider the logistics performance index throughout their several indicators instead of aggregating at the country level. We conclude that some indicators can affect positively while others can affect negatively or still be no significant to trade, at least at the soybean case.

Furthermore, the results indicate that logistics infrastructure has an important role in promoting soybean bilateral trade, confirming the concern of exporter and importer countries to improve the quality of movement corridors. Apart from this, the positive coefficient of distance and low impact of GDP suggest that soybean trade is connected to factors other than basic variables on gravity models such as cultural, land availability, and logistics costs.

Giving these findings, the study highlights that improvements in the logistics infrastructure of the exporters can move the soybean in the direction of one of those players. In the same direction, an enhancement in logistics infrastructure, logistics, quality and competence, and tracking and trace ability of the importer can improve the entrance of soybean in cargo ports. In the case of a highly integrated continent such as Europe, it may be represented a relevant competitive advantage to importer country.

Concerning the logistics variables that are significant and negatively correlated to soybean trade presented in the model, it may be claimed that the buyers' countries with a high index in customs variable do not necessarily consume more soybean, suggesting that a low index means a higher level of trade. Regarding the index of the custom of exporters, the concentration of exports in three players may have affected the result once two of three have a low custom indicator (Argentina 2.49, Brazil 2.53, and the US 3.76). In relation to international shipments and timeliness variables, they are connected to maritime transportation, which is highly controlled by the trading companies. Cargo flows consider pre-deterred schedules and they use storage areas as a buffer to cargo movement. This situation can affect the indicators of buyers regarding these two indicators. It is necessary to take into account that soybean flows are probably more influenced by trading companies than the countries. These results indicate the necessity of establishing further studies to understand de behavior of these specific indicators in the market.

This paper has an important contribution to logistics policy implications to countries dealing with agricultural commodities and with an extensive logistics network connecting productive areas to cargo ports. Soybean is a commodity dearly essential for the international community and the paper highlight the importance of considering local and external logistics factors on international trade.

Despite using a comprehensive sample of soybean trade in this study, the data we collected is not free of limitations. They are from different sources, and small inconsistencies may exist within the information obtained. These issues are due to the dynamic process of collecting agricultural and economic data from agencies and organizations (government and non-government). Furthermore, we need to consider that LPI revolves around a world survey that involves personal opinions and, consequently, can affect the indicator's reliability. However, it is the most comprehensive study on logistics that we have worldwide, and it remains an important tool for measuring logistics performance worldwide.

Another limitation of this study emerges from the traditional methodological complexity of studying trade. The effects of MRT were only partially addressed as we did not consider the time-variation on logistics variables [70], and despite our effort to circumvent possible endogeneity issues through the use of fixed effects, there is still reasonable concerns around that may also pose a limitation.

For further studies, the empirical analysis could be extended considering other different commodities or checking the role of the logistics performance over time. Finally, the list of variables was established based on previous studies, but future research could determine which variables are adequate to measure trade and logistics performance in agricultural commodities using empirical analysis and field research with growers, specialists, governments, and organizations bonded to the agriculture sector.

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Appendix A

Table A1. Variables and data sources.

Variable	Description	Source
Exports	Soybean bilateral exports from Argentina, Brazil, and the United States and their partners (2012–2018)	Argentina: INDEC: https://comex.indec.gob.ar/search; Brazil: MDIC: COMEXSTAT http://comexstat.mdic.gov.br/pt/gera; United States: U.S. Department of Agriculture, Foreign Agricultural Service: https://apps.fas.usda.gov/gats/default.aspx
Gross domestic product	GDP (US$) (2012–2018)	World Bank: The World Development Indicators. Economy & Growth: http://data.worldbank.org
Distance	Distance between relevant ports of soybean trade or the main port of the country	SEARATES https://www.searates.com
Indexes Customs, Infrastructure, International Shipments, Logistics, Quality and Competence, Tracking and Trace, and Timeliness	Logistics Performance Index the World Bank	Arvis et al. (2018)
Common language	Dummy variable that takes the value of 1 when the official language of both countries is the same and 0 otherwise	Author's elaboration
Common border	Dummy variable that takes the value of 1 when countries share physical boarders and 0 otherwise	Author's elaboration
Free Trade Agreement	Dummy variable that takes the value of 1 when countries share physical boarders and 0 otherwise	Author's elaboration using SICE/OAS data: www.sice.oas.org
Country size	Geographic area of the country	World Bank, https://data.worldbank.org/indicator

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