ABSTRACT

YILDIRIM, YASIN. Determinants of Brazilian Agricultural Exports (Under the direction of Dr. Heidi Schweizer).

Brazilian agricultural exports have increased roughly 12% per year since 2000 and the agricultural sector has been a critical contribution to growth in Brazilian GDP (Cepii-Chelem, 2021). Many explanations have been offered for the rapid rise of Brazilian market share in the global marketplace such as reductions in input costs, improved logistics performance, and a supportive policy environment. However, previous literature has been focused on specific crops and specific policies, and it is unclear which factors overall are associated with the largest increases to Brazilian agricultural export flows. Using a gravity model where the dependent variable is the value of Brazilian agricultural exports to its trading partners, the collection of factors commonly included in explanations of Brazilian agricultural and export growth between the years 1996-2018 are examined. Specifically, measures for currency depreciation, domestic agricultural policies, improvements to internal infrastructure (rail and road), changes in agricultural inputs like land-use and technology adoption- as well as the standard set of explanatory origin/destination variables such as bilateral trade agreements are included. Commonly used trade data (CEPII-CHELEM, World Bank Databank, OECD, FAO) with sources related to internal trade costs (CNT, DNIT, ANFAVEA) are combined. The obtained results show that improvements in domestic transportation infrastructure, more mechanized agriculture, and bilateral trade agreements promote Brazilian agricultural exports. Moreover, the growing economic size of Brazil and its trading partner increases the flow.

Determinants of Brazilian Agricultural Exports

by
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BIOGRAPHY

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1. INTRODUCTION

With the new relatively open Brazilian economy restructured by government reforms in 1990s, Brazil's agricultural export performance has exploded in a remarkable way. Total agricultural exports value of Brazil has increased approximately 12% each year for last two decades (Cepii-Chelem, 2021). The country has become a major supplier of many agricultural commodities in the global market like soybean, corn, poultry meat, coffee, cotton, raw sugar etc. (OEC, 2021).

The growth in agro-export plays a major role for the Brazilian economy. In 2020, almost 45% of Brazil's total export consists of processed and raw agricultural exports, while it was around 27% in 2000 (World Bank, 2021). This increase in the value has reached almost 90 billion USD and become the milestone of the positive trade balance of Brazil in recent years (OEC, 2021). The growth is also important for the global market. Brazil has become the main agricultural competitor of the Unites States for a few commodities in the global market. In the early 2000s, while the United States was the main supplier of soybean, corn, and poultry products, Brazil has surpassed the share of the United States and become the frontrunner for these commodities in the market (OEC, 2021). Hence, it is important to better understand the phenomenal growth of Brazilian agricultural exports both for the Brazilian government to maintain this rise with the right policies and for its competitors in global agricultural markets to evaluate their future agricultural exports.

Firstly, it is worth to evaluate macroeconomic conditions and policies of Brazil during the period of the rise. With government reforms in 1990s, new domestic policies took place in operation. The government has increased its support to farmers. From 1990 to 2015, removal of the agricultural price and output controls, enhancement of subsidized agricultural credit, reduction of agricultural tariffs, and dismantling of marketing boards for agricultural commodities were some agricultural policy trends of Brazil (OECD, 2021). The country has also increased foreign relations. Participations to WTO, Andean Community, Mercosur and the BRICS unity have taken place. However, during the term Brazil's had an economy characterized by instability. Higher inflation rates, constant currency depreciation, and frequent experience of economic recessions has become prevalent. The country has experienced two internal origin economic recessions during the period: the Samba effect (1999) and most importantly the Brazilian great recession (2014-16) as well as the 2008 World Financial Crises. Nevertheless, its competitiveness in agriculture sector has continued to grow.

Secondly, with the economic growth objective, Brazil has made a noticeable effort to improve its infrastructure. High government budgets have been allocated to several infrastructure programs: Brasil em Ação (Brazil in Action 1996-99), Avança Brasil (Forward Brazil 2000-03) which was later replaced by the PAC I (Growth Acceleration Program 2007-10), and lastly PAC II. During the implementation of these programs, thousands of miles of roads have paved and extended as well as railways, which has improved the market access, and lowered the production and transportation costs (CNT, 2021). For instance, the 2200 miles-long BR-163 highway, also called "The soybean highway" (because it transports the great majority of corn and soybean production), was proposed to be paved during the program Avanca Brasil (2000-03) and became totally paved in 2020.

Lastly, Brazil has had new arable land and fast-growing agricultural productivity. With the Plano Real going into effect in the mid-1990s, the market began to finance agriculture, which replaced the manpower with machines. This period was marked as the period of productivity, mechanization and professionalism for Brazilian agriculture (Baer, 2002). Also, there have been new land entering livestock and crop production that was previously amazon rainforest (Morton et al., 2006). These big changes in the production have an important place in hypothesis about export performance.

Although there have been studies focusing on specific products or policies of Brazil, no study has been found in the literature that deals with agricultural exports as a whole. Therefore, this study fills this gap by examining the factors behind the remarkable growth of Brazilian agricultural exports with a gravity model, covering 83 importing partners from 1996 to 2018. Unlike similar studies analyzing other particular countries, this study tries to explain the ascent by looking at six different points in addition to traditional gravity model factors: macroeconomic policies (supportive agricultural policies and trade policies), political stability and currency depreciation, domestic infrastructure change (road and railways), changes in agricultural inputs (land use and technology adoption as well as traditional ones), and domestic prices.

The rest of the thesis is organized as follows: Chapter 2 provides an overview of the Brazilian economy and agriculture. Chapter 3 reviews literature on the relevant gravity model studies. Chapter 4 presents the specified model, variables, hypothesis, data, and analytical approach. Chapter 5 discusses the obtained results, and Chapter 6 concludes.

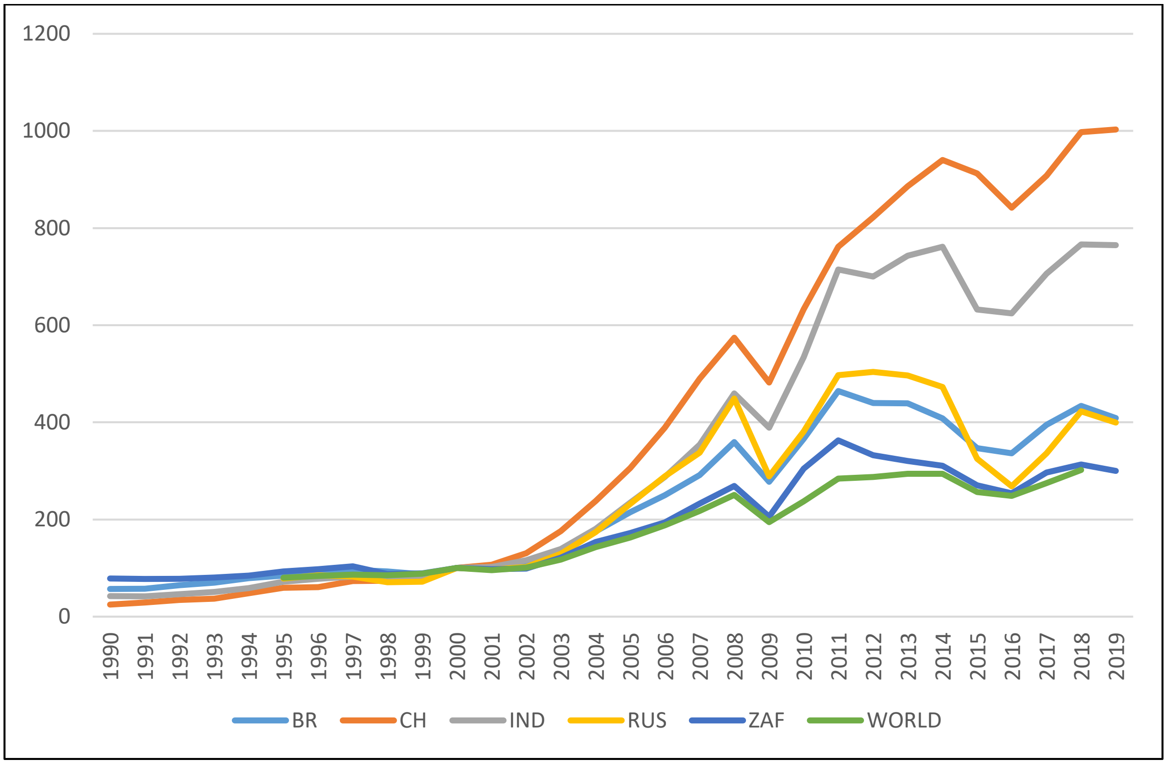
2. A REVIEW OF BRAZILIAN ECONOMY AND AGRICULTURAL EXPORTS

Before applying the gravity model, it might be helpful to mention Brazil's macroeconomic conditions and the agricultural sector. Thus, this section starts with an outlook of the Brazilian economy, giving some brief insights into the globalizing world and the Brazilian effort to keep up with the change. In the following, the Brazilian agricultural sector is scrutinized.

2.1 Brazilian Economy

With the establishment of the General Agreement on Trade and Tariffs (GATT), which covenanted to reduce trade barriers around the globe, the level of worldwide trade enormously developed with fast economic development around the world (Ray, 1998). Particularly after the 1980s, the volume has skyrocketed. Export-oriented industrialization, government subsidies for exports, reduced tariff barriers have become widespread in developing countries (Goldstein and Pevehouse, 2008). Figure 1 shows the exploded value of exports for BRICS countries and the world average. The average export value of the world tripled over the period. The export value got three times higher for South Africa, four times for Brazil and Russia, seven times for India, and ten times higher for China for the last two decades.

Figure 1. Export value index of BRICS and the world average (Based on 2000)



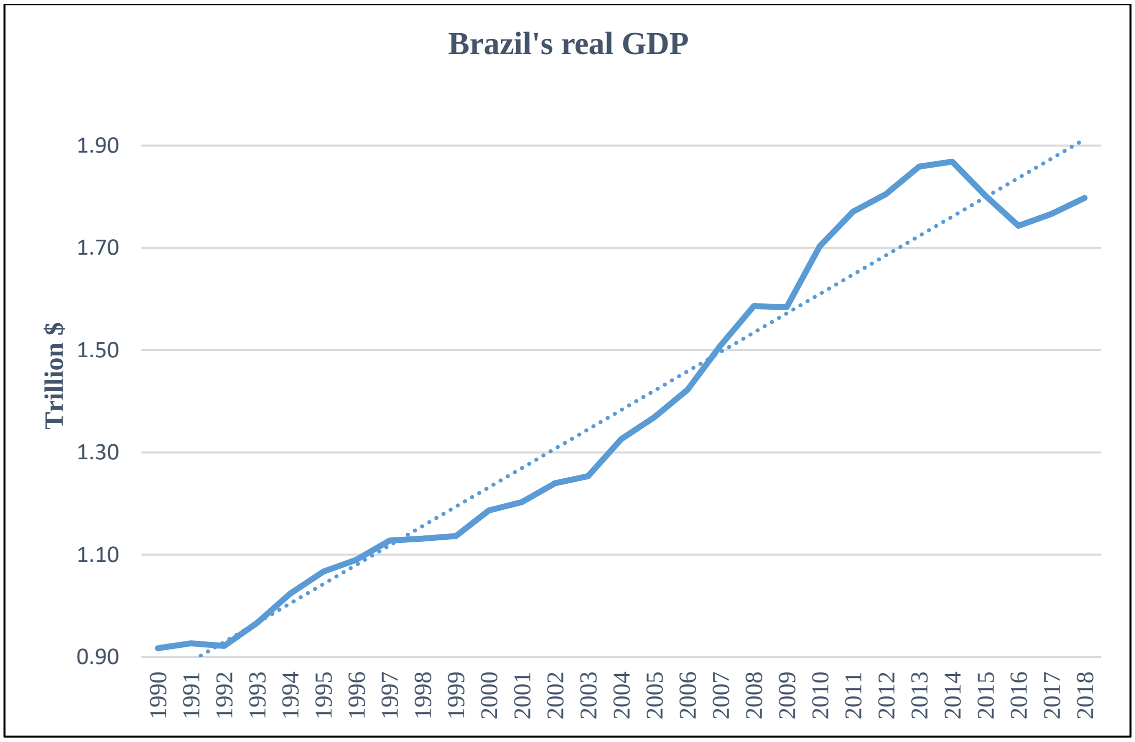
Data source: WITS, World Bank (2021)

Like many countries, Brazil liberalized its economy during the late 1980s and 1990s. The country pursued a relatively ambitious unilateral trade liberalization agenda in the first half of the 1990s, which was bolstered by the World Trade Organization's (WTO) consolidation of maximum tariffs for industrial and agricultural imports, as well as the founding of MERCOSUR's customs union (Veiga, 2017). Brazil's average applicable tariff fell from 21.2% in January 1992 to 14 % in July 1993 (WTO, 2021). Economic reforms have been supported by liberalizing changes in Brazilian legislation, such as the abolition of the concept of "Brazilian business with national capital" and the opening of several important areas to private and foreign participation (WTO, 2021).

The restructuring of the economy consequently promoted economic gain for Brazil. A significant accomplishment was the lowering of inflation from about 2,500% in 1993 to below

20% percent in early 1996. That was largely accomplished by the execution of Brazil's new stability program, the Plano Real, which was implemented in mid-1994 (WTO, 2021). With that new environment, Brazil's economic growth accelerated. Figure 2 shows the increasing real GDP of Brazil for the last three decades.

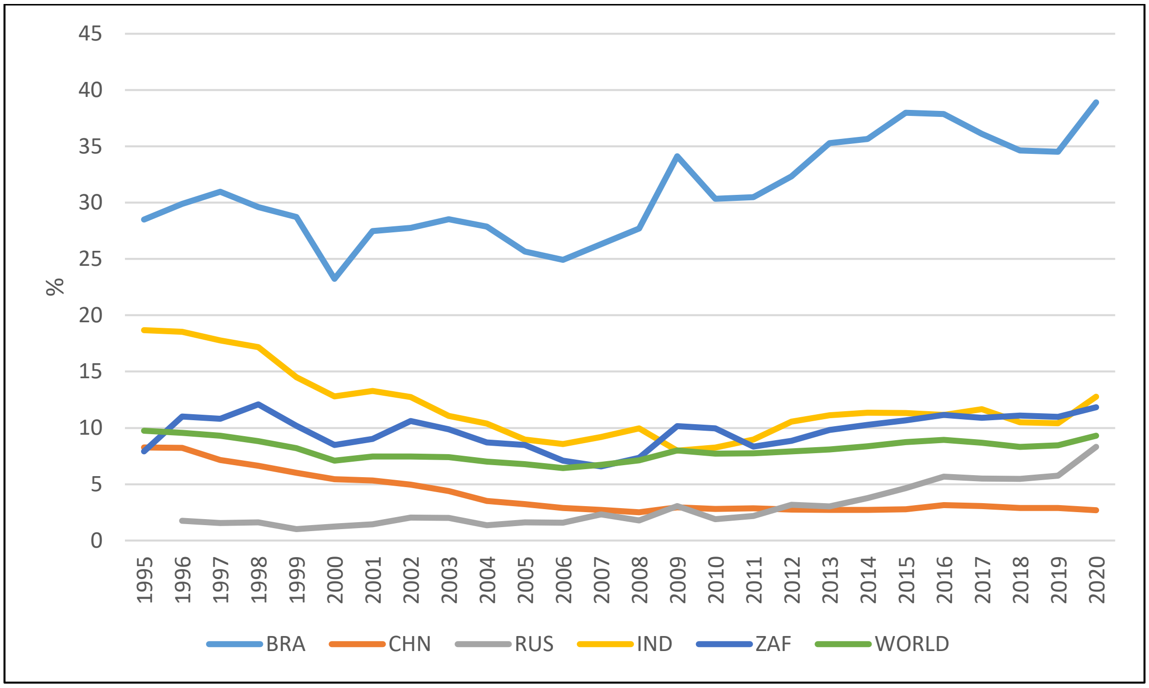
Figure 2. Brazil's Real Gross Domestic Product from 1990 to 2020 (Based on 2015 dollars)



Source: WITS, World Bank (2021)

The relatively liberalized Brazilian economy particularly boosted the agricultural sector. In figure 3, the share of food exports to total merchandise exports of BRICS countries and the world are shown. Over the period, from 1994 to 2020, the food exports share of Brazil has carried its importance and even increased while that of other BRICS countries has decreased or remained level.

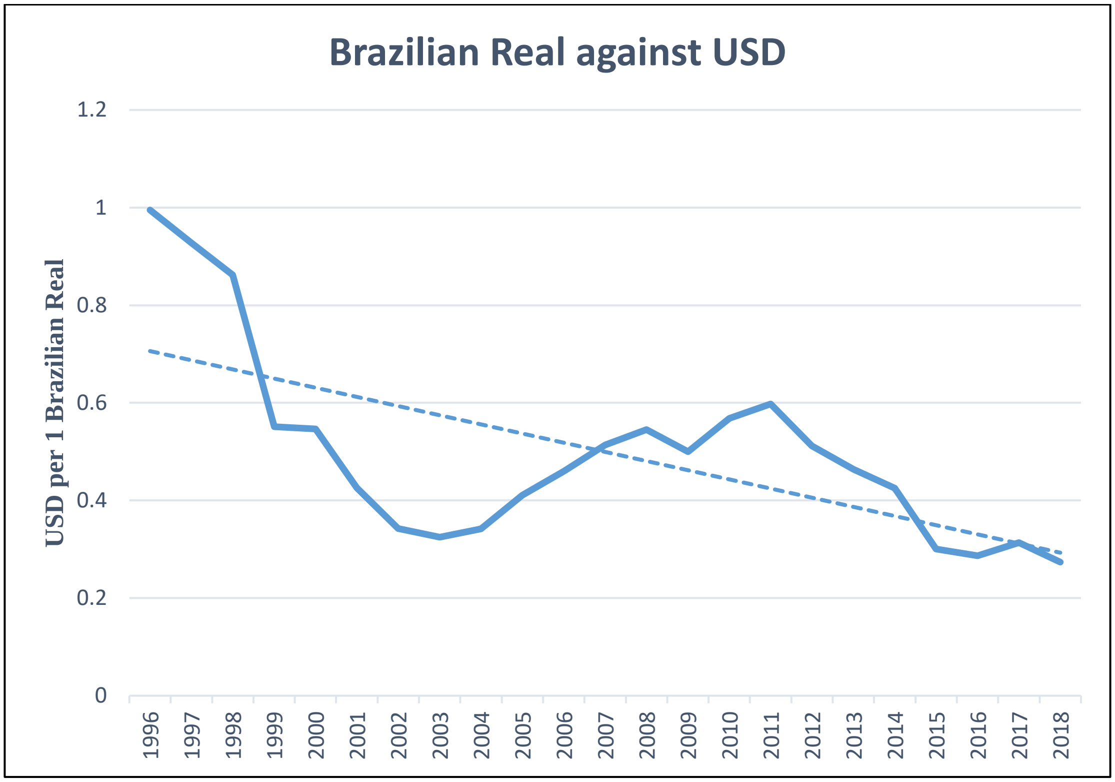
Figure 3. The share of food exports to total merchandise exports of BRICS and the world



Data Source: WITS, World Bank (2021)

On the other hand, even though Brazil has tried to stabilize its economy by new government reforms, economic crises and the national currency depreciation have become a feature of the economy. “The samba effect” in 1999 fueled by the Asian financial crisis made Brazilian Real weaken around %35. There was no economic growth for Brazil during this period as in the 2008 World Financial Crisis. During 2014-16, the country experienced the biggest economic downturn in its history: its GDP decreased by 3.5% in 2015, and 3.3% in 2016 (World Bank, 2021). During the two decades, the national currency has softened nearly 4 times. Figure 4 below shows how much depreciation has experienced the Brazilian Real against USD over the period of this study.

Figure 4. Brazil's currency depreciation from 1996 to 2018



Data Source: Darvas (2012)

2.2 Brazilian Agriculture

Covering nearly half of the South America Continent, Brazil is the fifth largest country in the world in terms of total land size and arable land. The country also has an attention-grabbing market size. It has the largest economy in Latin America, and the 8th largest in the world with a population of 213 million (World Bank, 2021). When it comes to the agriculture sector, Brazil approaches superpower status. It ranks as the number one crop producer and the number four food producer in the world after China, India, and the United States (FAO, 2021).

Agriculture has been the most stable and robust sector in the Brazilian economy. Whenever an economic recession occurs, it provides a buffering effect for the economy. From 1995 to 2014, Brazil's GDP had experienced 24 quarters of negative growth while the agriculture sector gave a positive growth rate for 17 of them. It also shows a strong growth when Brazil's GDP growth is strong (Arias et al., 2017). Based on those dynamics it has, the country is likely to preserve its competitiveness, notable in the agricultural sector.

Brazil has two main agricultural areas: Northern and Southern. The Southern has a moderate climate, and the region accounts for over two-thirds of the country. The soils are rich in nutrients, and the higher rainfall levels ensure that crops are well irrigated and fed. This region is also home to more advanced farming technologies and farmers with vast experience. Thus, this region produces the vast majority of the country's grains, export crops, and oilseeds. On the other hand, the northern agricultural region is much drier and less well-equipped. Due to low rainfall, it frequently succumbs to droughts and lacks infrastructure, capital, and soil. Subsistence farmers predominate in this region. However, certain goods from this region, such as cocoa, tropical fruits, and forest products, are critical exports. Besides, the central part of Brazil, Cerrado, has been booming for mechanized crop agriculture even though it was historically called unsuitable for agriculture. Since Brasilia was formed and specified as the new capital of the country in 1960, this previously isolated area with a lack of roads and other critical infrastructure has given way to crop cultivation (especially soybean) in this area (Meyer, 2010). Figure 5 shows the land structure of the country and the frequency of agricultural activities in those different regions.

Figure 5. The land structure of Brazil

Source: Sparovek et al. (2010)

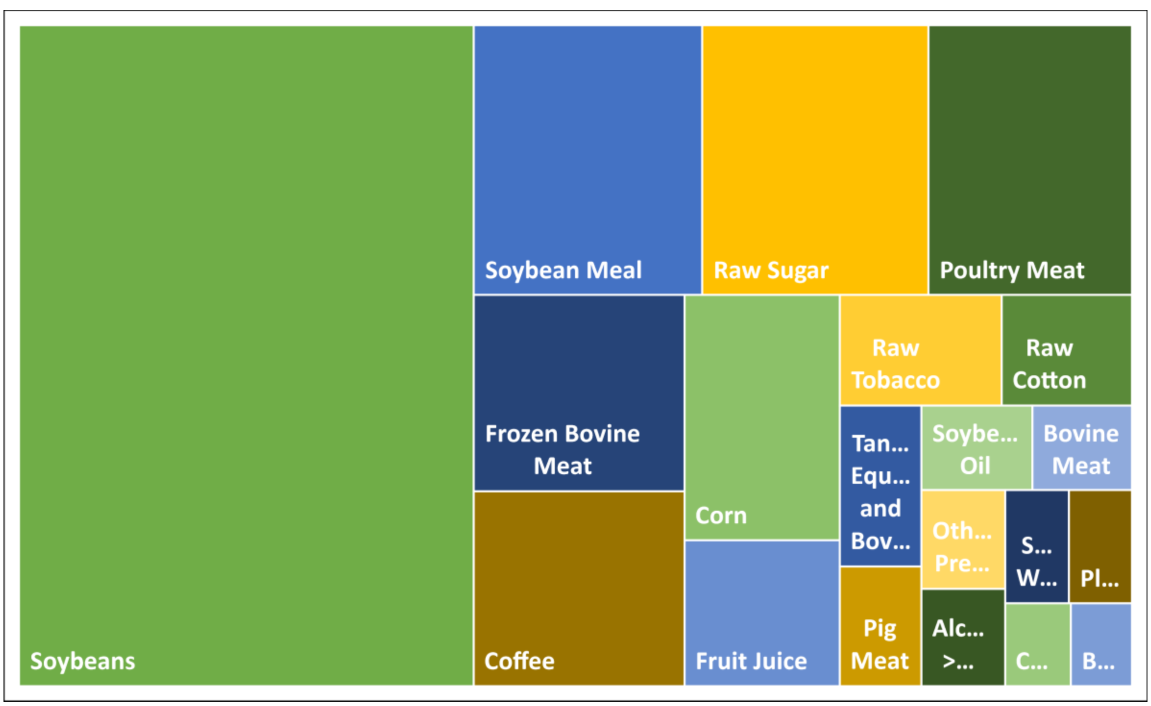
Before the 1990s, the country had an import-substitution strategy adopted in 1950s, which included wide-ranging government interventions in domestic market (OECD, 2021). During the period, government agencies regulated the domestic market. The agencies (SUNAB and CFP) exerted control over commodity supplies and prices by setting marketing, production and trade quotas.

As the Green Revolution period began in the world, there was a slow and horizontal expansion in Brazilian agriculture due to incorporation of more agricultural land. From 1950s to

1970s, the country increased its cultivated agricultural land by 82,5% (Benjamin et al., 2019). At this time, Brazil was a leading exporter of tropical fruits (Valdes et al., 2020). Then the modernization term began in the Brazilian agriculture from 1970s to 1990s. Agricultural research cooperation was founded in 1973 and government provided important financial support the sector, including subsidized credit to farmers, which resulted in higher yielding crops and diversification of crops (Benjamin et al., 2019).

After the 1990s, the sector has become a superpower in the world. With the effect of the liberalized economy, increased productivity with research and mechanization, and the policies of the Brazilian government to encourage agricultural production, Brazil has become the main supplier of strategic products like soybean, corn, cotton, meat, etc (Valdes et al., 2019). Figure 6 below shows the most exported Brazilian agricultural products in 2018, proportional to the area the products cover.

Figure 6. The most exported Brazilian agricultural products by monetary value in 2018



Data Source: OEC, 2021

3. LITERATURE REVIEW

This chapter is divided into two parts. The first section focuses on the theoretical development of the gravity model. The second section refers to agriculture-related studies of gravity model by paying particular attention to which product, industry, sector and/or country it targeted. It ends by giving the place of this study in the literature.

3.1 Theoretical Contributions to the Gravity Model

The Gravity model's growing popularity stems from its ability to empirically explain trade flows. The principal derives from Newton's gravity law, which states that with a force directly proportional to the sum of their masses and inversely proportional to the square of the distance between them, two bodies are attracted to each other. In the analysis of international trade, the theory around the gravity model follows the same logic in which the attraction force is represented by trade flows, imports or exports and the masses are represented by GDP, population or territorial expansion (Linneman, 1966). Tinbergen (1962) and Pöyhönen (1963) were the pioneer studies in applying gravity equation empirically to analyze international trade flows. According to these studies, trade flows have a positive relationship with economic sizes of countries and a negative relationship with physical distance between countries. In following work, different variants of the gravity model were used to offer a strong theoretical foundation to the gravity equation. Among these, Linneman (1966), Anderson (1979), Bergstrand (1985; 1989), Helpman (1987), Deardorf (1988), Anderson and Wincoop (2003) were pioneering studies in building the gravity model on a solid theoretical basis.

To start with, Linnemann (1966) added three new factors to the basic model: the exporting country's potential supply, the importing country's potential demand, and lastly trade barriers. Accordingly, he added population, relative factor endowments, trade resistance, economic distance, and trade preferences variables. Another addition made by Linneman was the significance of having similar cultural backgrounds.

Anderson (1979) further developed the theoretical framework by using a Cobb-Douglas type of expenditure function in his model. He made two basic constraints on the model: similar preferences among countries and differentiation of products by place of origin (for the first time). He also contributed to the clarification of its log-linear form and the presence of an income variable in the equation.

Bergstrand (1985) adopted the Anderson's model highlighting that the gravity equation without price and exchange rate variables is shortcoming. Later on, Bergstrand (1989) extended his previous microeconomic foundations by drawing attention to the factor endowment differences between countries and the argument that countries do not have similar preferences. Accordingly, he divided goods into luxury and necessary, and added per capita income variable.

Helpman (1987) used monopolistic competition model in differentiated products with data for the first time. He observed that the trade volume between countries and the economic size of the countries move together over time, and the trade volume between them grows as the countries grow economically. His all-main predictions relied on Helpman and Krugman (1985) were consisted with the data.

In the studies of Helpman (1987) and Bergstrand (1989), product differentiation among firms was assumed rather than among countries. With this assumption, they departed further from the Heckscher-Ohlin and the Ricardian model (Deardorff, 1998). These two are another mathematical model of international trade. According to the Ricardian model, technologies differ among countries, therefore each country specializes in producing the goods in which it has a comparative advantage. The Heckscher-Ohlin model, built on the Ricardian model, says that countries export the goods that use their abundant and cheap factors of production (capital and labor) and import the goods that use the countries' scarce factors. The way it differs from the comparative advantage of Ricardo is the efficiency of the production process based on the factor endowment of countries.

Deardorff (1998) argued that, unlike the literature, the Heckscher-Ohlin model may be compatible with the inferences from the gravity equation in some cases. He claimed that a simple gravity equation can be obtained from a correctly constructed Heckscher-Ohlin model for both the presence and absence of trade barriers. The evaluations also revealed an idea about the reasons for the failure of the gravity equation to explain trade flows in some cases.

Anderson and van Wincoop (2003) developed a method that consistently and efficiently estimates the gravity equation and accurately predicts the comparative statics of trade frictions within the framework of the general equilibrium model. Differently, they related bilateral trade to economic size, and added multilateral resistance variables as well as bilateral trade variables. With their method, they successfully solved the famous McCallum (1995) border puzzle and concluded that trade volume between countries decreased substantially because of borders.

Especially with the famous border puzzle being solved by Anderson and van Wincoop (2003), the gravity equation has been commonly used in empirical analysis of international trade. Even the gravity model had a separate chapter in a textbook written by Feenstra (2004) (Shahriar et al., 2019). Because it has been frequently used, there are several types of models appearing in the literature in accordance with the nature of the data and estimation methods (Shahriar et al., 2019). This plenitude provides a strong guide for studies. Yotov et al. (2016) dedicated the popularity and success of the gravity equation to five distinct reasons: the intuitive and strong basis, realistic, flexible structure and robust predictive power. It's been also frequently utilized to examine global agricultural trade. Next section provides several applied works in agricultural trade that used the gravity model.

3.2 The Gravity Model Applied to Agricultural Trade

Since 1990, there have been studies investigating agricultural trade with the gravity model of trade. While some of them have focused on a single-commodity trade such as coffee and rice, or agro-industry such as oilseed, some studies have concentrated on the agriculture sector as a whole. The following part will scrutinize the ones investigated on aggregate agricultural data of particular countries with gravity model since they are similar to this study.

In general, the obtained findings for studies dealing with agricultural exports are in line with the theoretical framework of the basic gravity model. While the economic size of the trading partners increases the trade volume between the two countries, the increasing distance reduces it. A considerable amount of such studies has considered exchange rate volatility, and a positive impact of national currency depreciation on agricultural exports has been confirmed. On the other hand, a few studies have appeared in the literature with surprising results. For instance, Said and Shelaby (2014) found common border between Egypt and its partner reduces agricultural trade volume. Braha et al. (2017) claimed growing domestic market size of Albania reduces its export volume, and a negative effect of preferential trade agreements on Algerian agricultural exports was determined by Matallah and Benmehia (2019).

Sevela (2002), as an example of research on the agricultural trade with aggregate data, applied the gravity model to investigate the major determinants of agricultural export for Czechia. He found that distance and GNI per capita have a negative impact on Czech agricultural exports, contrary to Gross National Income (GNI).

Erdem and Nazlioglu (2008) analyzed Turkish agricultural exports to European Union (EU). Distinguishably from similar studies, they considered the agricultural land size of importing countries and climate differences between the trading partners. Also, they included a variable representing the Turkish population living in the EU since a considerable amount of Turkish people live in the EU countries. They concluded that agricultural exports of Turkey to the EU are positively correlated with the economic size of two sides, the membership to the EU-Turkey Customs Union, the Turkish population living in the EU, and the climate difference. On the other hand, as expected, they found greater distance and arable agricultural land of importing countries harm the export flow.

Another important contribution to this literature was made by Hatab et al. (2010). They analyzed the determinants of Egyptian agricultural export, covering 50 importing partner from 1994 to 2008. They concluded that currency depreciation and economic size of Egypt positively influences the export performance while the growing population and greater distances decreases it. Said and Shelaby (2014) also examined the agricultural trade performance of Egypt. In addition to the export, they considered the import performance from 1995 to 2010 with 9 Arab countries. Their findings were in line with basic gravity model for both agricultural exports and imports. Surprisingly, they found that a common border between Egypt and its trading partner reduces the import volume.

Serrano and Pinilla (2011) contributed to the literature with a comprehensive study covering the time period from 1963 to 2000 for EU countries to determine the evolution of EU agricultural trade flows. They broke down the agricultural export into four product groups and separately analyzed intra-regional trade flows, export and import flows as well as a complete panel analysis. They stated that the EU's agricultural exports became increasingly concentrated among economies with a large market size; per capita GDP growth boosted exports and reduced imports, while EU internal market liberalization boosted intra-regional trade. Furthermore, the presence of the home market effect, which is characteristic of a pattern of intra-industrial trade, was associated with a surge in the EU's agricultural supply capacity, while its imports were strongly influenced by the effects of intra-EU trade liberalization, as was the case with intra-EU trade flows.

Khiyavi et al. (2013) assessed the factors affecting the international trade of agricultural products in 14 developing countries from 1991 to 2009. According to their results, agricultural exports of developing countries are influenced by the economic size of home and partner countries. They also found that while the per capita GDP of those developing countries has a positive impact on their export, that of partner countries is correlated negatively with their export performance.

Another agricultural sector-specific gravity model research was done by Ebaidalla and Abdalla (2015). To identify the determinants of Sudanese agricultural exports and to investigate whether there is unexploited trade potential between Sudan and its trading partners within this sector, they examined 31 importing partners of Sudan between 1991 to 2015. The factors indicating the economic size of importing countries, GDP and population, have a positive effect on Sudan's agricultural export. Also, having a trade agreement and sharing the same language increases the trade volume, while distance reduces. They also included an infrastructure variable for both sides considering telephone lines, which shows that it increases the exports. In addition, Sudan has unexploited export potential with, particularly, Oman, Spain, Poland, Singapore, Japan, Finland, and Mexico. Also, they mentioned agricultural export to Jordan and Saudi Arabia exceed their exports potential.

With the same motivation, Braha et al. (2017) analyzed Albanian agricultural export to figure out its determinants. The study, which includes 46 importing partners from different trade blocks between 1996 to 2013, showed that as the population grows, so does domestic demand, resulting in a decrease in agricultural exports. Low transportation costs (distance), adjacency proximity, language affinities, and the presence of Albanian Diaspora in importing nations all influence Albanian agricultural export flows. Also, they mentioned while bilateral institutional distance has diminishing effects, exchange rate variability has a positive impact on the exports.

Aguirre et al. (2018) covered 12 importing countries within two regional groups from 1990 to 2010 to find the determining factors of Nicaraguan agricultural exports. The variable indicating the level of development (per capita GDP) of both sides found positively correlated with the export flow as well as real exchange rate and population of trading partners. As expected, export volume decreases as distance increases. They also found FTAs predominantly affect the trade.

Matallah and Benmehaia (2019) did wide-ranging research to investigate Algerian food exports, covering a total of 98 countries from 2001 to 2017. The researchers found, just like others, distance negatively influence the Algerian food export while domestic and foreign demand, cultural relationship, and adjacency affect it positively. Surprisingly, they revealed FTAs hurt the export.

Uzel and Gurlek (2019) carried the same purpose for Turkey’s agricultural exports. Their study covered 16 agricultural trade partners of Turkey for the period of 30 years, from 2001 to 2030. They included variables indicating per capita animal protein consumption and agricultural product value as well as basic GMT variables. Their results were in line with the conventional gravity model, the economic size of trading partners (population and GNI) positively correlated with the dependent variable, while the indicator of transportation costs has a negative impact on it. Also, they found the home country would export more as per capita animal consumption of destination countries increases.

As seen above, this model has been used many times by researchers for the analysis of agricultural trade. In addition to commodity and industry-specific ones, several agricultural sector-specific studies have contributed to the literature, as referred above, taking aggregate agricultural data of particular countries such as Chechia, Turkey, Egypt, Pakistan (See Table Xa and Xb below for complete relevant literature). Similarly, this study tries to contribute to the literature by applying the famous gravity model of trade to the remarkably increasing agricultural export of Brazil. In the literature, no study has been found that examines determinants of agricultural export of Brazil. It is important that Brazil has become quite competitive in agricultural products with high global market share such as soybean, and that the country constantly increases its competitiveness in the global market more and more. Furthermore, the country has attached significance to this issue and tried to protect the competition with appropriate policies, which stimulates an investigation on. Unlike similar studies, this study evaluates many more factors combining national data sources and commonly used trade data. Evaluating the effect of different factors like internal transportation costs and agricultural inputs change is not frequently encountered in the existing literature of gravity model of agricultural trade. Moreover, points specific to Brazil, such as the fact that it covers a large part of the Amazon rainforest, the prolonged depreciation of the national currency, and over-experienced economic recessions encourage the issue to be addressed. Besides how different and important traditional variables are for Brazil's agricultural exports, it arouses curiosity to what extent they contribute to this rise in different factors. Thus, this study tries to answer those questions and fill the literature gap for Brazil by applying the well-known gravity model of trade.

Table 1. Aggregated Brazil-specific and agricultural sector-specific gravity model studies

Data type	Flow type	Author and Year	Aim	Estimation Method	Sample	Explanatory Variables
Aggregated Ag. Sector-specific	Export	M. Sevela (2002)	Examination of the factors that affect the volume of Czech agro-exports	WLS	Not given 1999 to 2001	GNI&GNIPC&DIST&REX TAR&EU&EFTA
Aggregated Ag. Sector-specific	Export	Erdem & Nazlioglu (2008)	Examination of the factors that affect Turkish agricultural exports to the EU	RE	23 countries 1996 to 2004	GDPit &GDPjt&POPjt&DISTij ArableLANDj&TurkPopj &CustomUnionj&NonMEDj
Aggregated Ag. Sector-specific	Export	Hatab et al. (2010)	Examination of determinants of Egyptan agro-export	FE	50 countries 1994 to 2008	GDPi & GDPj&GDPPCi &GDPPCj OPENNESSit & OPENNESSjt &DIST&ADJ&LANGj &EXCijt & FTAijt
Aggregated Ag. Sector-specific	Bilateral	Said & Shelaby (2014)	Examination of the determinants of Egyptian agricultural trade with the Arab countries	OLS	9 countries 1995 to 2010	GDPit & GDPjt & GDPPCjt & DISTij &FDIit & FDIjt ADJij
Aggregated Ag. Sector-specific	Import	Lee and Lim (2014)	Examination of determinants of Korea's imports of agricultural products from the LDCs and OECD	HTS FE RE	38 OECD + 41 LDCs 2003 to 2008	GDPit & GDPjt &DISTij & FTAijt & EXCijt & TARijt & TradeFreqeuncy
Aggregated Ag. Sector-specific	Export	Braha et al. (2017)	Examination of the determinants of Albanian Agricultural Exports	PPML	46 countries 1996 to 2013	GDPi&GDPj&POPi&POPj&DISTij GDPPCij&ADJ&CL&COL&LANDj DIA&BEXC&INFj&EFTA&CEFTA SAA&FTAtur& INSDISTij
Aggregated Ag. Sector-specific	Export	Kiani et al. (2018)	Examination of the effects affecting Pakistan's rice and cotton exports	RE	10 countries 1984 to 2014	GDPi&GDPj&POPi PRODi&DISTij&BORij
Aggregated Ag. Sector-specific	Export	Aguirre et al. (2018)	Examination of the determinant factors of Nicaraguan agricultural exports	OLS	12 countries 1990 to 2010	GDPPCit&GDPPCjt&POPjt &DISTij& EXCijt &ADJij&Langij&SEA&FTA
Aggregated Ag. Sector-specific	Export	Matallah & Benmehaia (2019)	Examination of the major factors that influence Algerian food exports	WLS	98 countries 2001-2017	GDPi&GDPj &POPi&POPj DISTij&ADJij&CULTUREij &FTA
Aggregated Ag. Sector-specific	Export	Uzel & Gurlek (2019)	Determinants of Turkish agricultural exports	RE	16 countries 2001 to 2030	GNP&POP&DIST &PRODVAL &animalproteinconsjt
Aggregated Brazil-specific	Bilateral	Porto (2002)	Examination of the impact of the MERCOSUR on Brazil's regions	OLS	Not Given 1990, 1994, 1998 (3 years)	GDPi&GDPj&POPi&POPj DISTij&ADJ&Mercosuldummy EFTAdummy&Eudummy Brregiondummy
Aggregated Brazil-specific	Bilateral	Sireon & Yucel (2011)	Examination of the consequences of MERCOSUR on the direction of Brazilian trade	PPML	118 countries 1991, 1997, 1998, 1999 (4 years)	GDPi&GDPj&DISTij CONTIGUITYi&RTA&IST MERCOSURdummy
Aggregated Brazil-specific	Bilateral	Guilhoto et al. (2015)	Estimation of the determinants of the Brazilian states' external trade	OLS and PPML	81 countries 2008 (Cross-sectional)	GDPstate&PRODstate COLLONIALstate &REMOTNESSstate Landlocstate&DISTstate
Disaggregated Brazil-specific	Export	Valerius et al. (2017)	Examination of Brazilian exports of softwood moldings	RE	57 countries 1997 to 2013	GDPi&GDPj&POPi&POPj&DIST
Aggregated Brazil-specific	Export	Ribeiro (2019)	Examination of the behaviour of aggregate Brazilian exports	OLS and RE	35 countries 2000 to2016	EXPORT&EXPORTPC&GDPi &GDPj&GDPPCi&GDPPCj&DIST &NAFTAdummy&Eudummy &MERCOSURdummy
Aggregated Brazil-specific	Export	Viera & Reis (2019)	Examination of the determinants of Brazilian exports by levels of technological intensity	PPML	15 countries 2000 to 2015	GDPPCi&GDPPCj&POPj&DISTij relativeDISTij&diffrGDPPCij TARj&LANDj&ADJij&FTAij CRISIS2007&CRISIS2008

Table 2. Disaggregated agricultural sector-specific gravity model studies

Data type	Flow type	Author and Year	Aim	Est. Method	Sample	Explanatory Variables
Disaggregated Ag. Sector-specific	Bilateral	Koo et al. (1994)	Examination of the factors affecting trade flows of meat	OLS	8 countries 1983 to 1989	GDPMEATit&GDPjt&Pi&Pj &EXCijt&DISTij&PRODi &PRODj&PSEi&CSEj&Quota &Diseasedummy&Adj
Disaggregated Ag. Sector-specific	Export	Atici & Guloglu (2006)	Examination of determinants of Turkey's fresh and processed fruit and vegetable exports to the EU	RE	13 countries 1995 to 2001	POPj&GDPj&DISTij TRPOPj&MDTjdummy
Disaggregated Ag. Sector-specific	Bilateral	Jayasinghe & Sarker (2008)	Examination of the NAFTA on trade in 6 agri-food products	GLS	57 countries 1985 to 2000	GDPit & GDPj&GDPPCit &GDPPCjt&DISTij
Disaggregated Ag. Sector-specific	Export	Kumar (2010)	Examination of the factors affecting the growth of livestock export	Not given	Not given 1980 to 2007	GDPlivestocki&PRODi&PPPi GDPj&GDPPCj&TradePoli&DISTij
Disaggregated Ag. Sector-specific	Export	Idsardi (2010)	Examination of the factors contributing the agro-export growth of South Africa	OLS	Not given 2002 to 2009	GDPi&GDPj&GNIi&GNIj&DISTij EconDISTij&POPj&EXCij&IMPj ADJ&SADC&TDCA
Disaggregated Ag. Sector-specific	Export	Angulo et al. (2011)	Examination of the impacts on Tunisian olive oil export	Spatial M.	6 countries 2001 to 2009	GDPj&HDIj&DISTij&CL
Disaggregated Ag. Sector-specific	Bilateral	Serrano & Pinilla (2011)	Examination of the determinants of the evolution of EU agricultural trade flows	FE	40 countries (the most in 4 models) 1963 to 2000	GDPit&GDPjt&GDPPCit &GDPPCjt&DISTij&EXCijt &RDISTij&ADJ&CL&GATT &C_EU&D1_EU&D2_EU
Disaggregated Ag. Sector-specific	Bilateral	Xia et al. (2012)	Examination of the impacts of transportation costs on international oilseeds trade	OLS FE	22 countries (2009)	GDPi&GDPj&DISTij ADJij&mrDISTij&mrADJ
Disaggregated Ag. Sector-specific	Export	Ahmad & Garcia (2012)	Exemination of the factors that affect Pakistan's rice export and unexploited rice export potantial	FE	92 countries 1991 to 2010	GDPj&GDPi&GDPPCj&GDPPCi Pij&EXCij&DISTij& CHij
Disaggregated Ag. Sector-specific	Bilateral	Sheldon et al. (2013)	Examination of the effect of exchange rate uncertainty on the US' bilateral fresh fruit and vegetble trade	OLS FE	Fruit: 26c 1976 to 1999 Vegt: 9c 1976 to 2006	GDPi&GDPj&POPi&POPj&DISTij EXCij&LANGdummy&FTAdummy
Disaggregated Ag. Sector-specific	Export	Khiyavi et al. (2013)	Examination of the factors that affect agriculture trade on developing countries	FE	14 countries 1991 to 2009	GDPi&GDPj&GDPPCj&GDPPCj DISTij&EXCij&4FTAdummies
Disaggregated Ag. Sector-specific	Export	Ebaidalla & Abdalla (2015)	Examination of the determinants of Sudanese agricultural exports and unexploited trade of Sudan	RE	31 countries 1991 to 2015	GDPit&GDPjt&POPi&POPj INFRi&INFRj&DISTij&REXij& INSTi&CL&COL&RLG COM&EU&ASIA
Disaggregated Ag. Sector-specific	Export	Bui & Chen (2015)	Examination of the factors that affect Vietnam's rice export	FE	15 countries 2000 to 2013	PRODi&DISTij &EXCi&EXCj IMPij&GDPj&GDPi&INCj&INCi POPj&Pi&ASEAN&ADJ&PARTNER (if vieatnam 1st)
Disaggregated Ag. Sector-specific	Export	Ozer & Koksal (2016)	Examination of the primary factors that influence Turkey's citrus exports	Quantile R.	60 countries 2007 to 2012	GNPPCj&POPj&DISTij&REXC EUjdummy&BLACKSEAidummy&PRODi
Disaggregated Ag. Sector-specific	Export	Atif et al. (2017)	Examination of the main factors influencing Pakistans's agro-export and untapped export potential of Pakistan	MLE	63 countries 1995 to 2014	GDPit&GDPjt&DISTij&TARijt EXC&ADJij&Language &Colony&PTA
Disaggregated Ag. Sector-specific	Export	Kiani et al. (2018)	Examination of the effects affecting Pakistan's rice and cotton exports	RE	10 countries 1984 to 2014	GDPi&GDPj&POPi PRODi&DISTij&BORij
Disaggregated Ag. Sector-specific	Export	Shahriar et al. (2019)	Examination of the determinants of China's pork exports	PPML	31 countries 1997 to 2016	GDPi&GDPj&GDPPCi&GDPPCj POPi&POPj&DISTij&LANDj EXCij&LANGdummy&ADJdummy WTOdummy&SEAdummy&BRIdummy
Disaggregated Ag. Sector-specific	Export	Baker & Yuya (2020)	Examination of the determinant factors of Ethiopia's sesame exports performance	RE	11 countries 2002 to 2014	GDPi&GDPj&POPi&POPj REXCij&INFi&WeightedDISTij
Disaggregated Ag. Sector-specific	Bilateral	Nasrullah et al. (2020)	Examination of the trade specialisation of forest product group of China	FE	50 countries 2001 to 2018	GDPi&GDPj&DISTij&POPi&POPj FDIj&EXCj&LANDi&LANDj OECDjdummy&APECjdummy LANGjdummy GECjdummy&CVD/Adjdummy
Disaggregated Ag. Sector-specific	Export	Eshatu & Goshu (2021)	Examination of export determinants of Ethiopian coffee	GMM	31 countries 1998 to 2016	GDPi&GDPj&POPi&POPj WeightedDISTij&OPENj&INSQi

4. METHODOLOGY

This chapter covers four sections: firstly, the model is specified, followed by the definitions of included variables and the hypotheses. Then, the sample size and the dataset are detailed, and it finishes with the used techniques for the analysis.

4.1 Model Specification

In this study, a gravity model is specified for Brazilian agricultural exports. The basic form of the gravity equation is as follows:

$$T_{ij} = A \times \frac{GDP_j^{ß} GDP_i^{\alpha}}{D_{ij}^{\theta}} \quad (1)$$

In equation (1), Tij represents bilateral trade between Brazil and country j; A refers to constant; GDPj represents the economic size of recipient countries, and GDPi represents the economic size of Brazil; Dij indicates the distance between Brazil and its trading partner. The Greek letters α, β, and θ are parameters that are often estimated in a log-linear reformulation of the model. This formula explains bilateral trade using economic size and distance: the greater the two trading partners, the greater the flows of trade; the greater the distance between the two countries, the smaller the bilateral trade. Generally, the model explains 70–80 percent of the bilateral trade flow variance (Bergeijk et al., 2009).

By transforming the basic form of the gravity model, the logarithm of the trade volume between Brazil and country j, is regressed on the logarithm of the economic size of Brazil, that of country j, and the logarithm of the distance between them. The formula (1) reformulated by applying natural logarithmic can be written:

$$lnT_{ij} = ln\mathrm{A} + alnGDP_i + \beta lnGDP_j - \theta \mathrm{lnD}_{ij} \quad (2)$$

There is a need to insert more variables beyond the original ones to analyze international trade flows through the gravity model since they alone cannot explain the massive variations in trade flows. Accordingly, as given in more detail in the previous chapter, most researchers have added new variables with less theoretical justification into the basic gravity model, like cultural links and adjacency (Head, 2003). Inevitably, several alternative specifications have been made for the gravity model regarding particular countries and commodities. Having the equation (2) above, the augmented gravity equation for the Brazilian case, concerning the changing dynamics of the country discussed in chapter 2, would be formulated as:

$$\begin{aligned} lnAGEX_{jt} = {} & \beta_0 + \beta_1 lnGDP_t + \beta_2 lnGDP_{jt} + \beta_3 lnDIST_j + \beta_4 lnBEXC_{jt} + \beta_5 lnPSE_t \\ & + \beta_6 lnROAD_t + \beta_7 ROADQ_t + \beta_8 lnRAIL_t + \beta_9 laglnMACH_t + \beta_{10} AGLAND_t \\ & + +\beta_{11} AGLAND_{jt} + \beta_{12} lnFERT_t + \beta_{13} lnPEST_t + \beta_{14} PPI_t + \beta_{15} INSQ_t \\ & + \beta_{16} TRADEFREE_{jt} + \beta_{17} PTA_{jt} + \beta_{18} ADJ_j + +\beta_{19} LANDLOC_j + u_{ijt} \end{aligned} \quad (3)$$

Where:

j = Importing partners of Brazil, t = Time, β_0 = Intercept, β_k = Slope, u_{ijt} = Error term

$lnAGEX_{jt}$ = Logarithm of Brazil's agricultural exports to country j at time t

$lnGDP_t$ and $lnGDP_{jt}$ = Logarithm of real GDP of Brazil, and country j at time t, respectively

$lnDIST_j$ = Logarithm of physical distance between the capital cities

$lnBEXC_{jt}$ = Logarithm of the bilateral real exchange rate between Brazilian Real and country j's national currency at time t

$lnPSE_t$ = Logarithm of producer support estimate value in Brazil at time t

$lnROAD_t$ = Logarithm of total road length (paved and non-paved) in Brazil at time t

$ROADQ_t$ = The ratio of paved roads length to total road length in Brazil at time t

$lnRAIL_t$ = Logarithm of total railways length in Brazil at time t

$laglnMACH_t$ = Logarithm of the number of agricultural machinery sales in Brazil at time t (lagged by one year)

$AGLAND_t$ = Agricultural land share to total land of Brazil at time t

$AGLAND_{jt}$ = Agricultural land share to total land of country j at time t

$lnFERT_t$ = Logarithm of the amount of fertilizer used in agricultural activity in Brazil at time t

$lnPEST_t$ = Logarithm of the amount of pesticide used in agricultural activity in Brazil at time t

PPI_t = Agricultural Producer Price Index in Brazil at time t

$INSQ_t$ = Institutional Quality Index of Brazil at time t

$TRADEFREE_{it}$ = Trade Freedom Index of country j at time t, respectively

PTA_{jt} = Dummy for existent Preferential Trade Agreement between Brazil and country j at time t

ADJ_j = Dummy for common border between Brazil and j

$LANDLOC_j$ = Dummy for land-locked country j

4.2 Variables and Hypothesis Development

The dependent variable ($lnAGEX_{jt}$) is deemed to be the value of the agricultural export from Brazil to recipient countries at time t. These values were deflated using the export price index based on 2010 from SECEX (Secretaria de Comércio Exterior of Brazil). The real values were reached by multiplying the nominal export values with the index of each year.

Real Gross Domestic Product ($lnGDP_t$ and $lnGDP_{jt}$) of the trading countries are one of the independent variables considered to be the main actor in the basic gravity model. GDPs are used as a proxy for a country's economic size since they represent both production and consumption capacity, which determines the majority of trade flows between them. The importing country's

GDP determines the demand for products originating in exporting countries, and an exporting country's GDP also contributes to determining production capacity, or the number of products that can be supplied. Thus, it is expected that the coefficient of the both variables to be positive since they are a source of expansion of Brazil's agricultural exports.

The variable distance ($lnDIST_j$) is the geographic distance between capital cities of the trading partners, so it is a fixed variable over time. It is another essential part of the conventional gravity model, which is used as a proxy for the trade cost between countries. Besides transportation costs, it represents trade barriers such as delivery time, cultural unfamiliarity, and market access barriers. The distance can also be used as a proxy for the risks associated with some of the goods' quality and the cost of personal contact between managers and customers. Taking all this into account, long distances serve as a trade barrier for countries that want to engage in trade. Therefore, countries that are close to each other are expected to trade more than those that are far apart. Hence, this aspect is projected to have a negative impact on the exports.

The adjacency (ADJ_j) is the second geographical variable of the equation, which shows the common border between Brazil and the recipient country. It is a binary variable of the model, and it equals one if Brazil and its trading partner have a common border and zero otherwise. Regarding low transportation costs and close preferences, trade between neighbor countries is expected to be higher when compared with other non-neighbor countries. The sign of the variable's coefficient is expected to appear positive.

The variable ($LANDLOC_j$) is another dummy indicating whether country j has access to oceans or not. It equals zero if country j has at least one port, and one otherwise. Since the ports are an important part of trade transactions, and the absence of them can increase transportation costs, the sign of the coefficient is predicted negative. Although Kazakhstan has a port on the

Caspian Sea, the variable for the country is marked as zero since the Caspian Sea has no access to any ocean.

The real bilateral exchange rate ($BEXC_{jt}$) is another independent variable used in this study as it has been included many times in the literature that tries to explain agricultural trade with the gravity model. The exchange rate is the value of one country's currency expressed in the national currency of another country. In other words, the exchange rate at which one national currency unit can be converted into another. A depreciation boosts economic growth through improving capacity utilization and enhancing the profitability of traded goods industries. That leads to increase private investment in the country as well. Also, a depreciated currency provides an economic incentive for new prospective exportable products that would otherwise face significant entry barriers under an overly strong currency. For these reasons, the depreciation of a country's national currency against another one is expected to increase the export volume of this country. This variable is defined as one unit of foreign currency against one unit of Brazilian Real (BRL/Foreign currencies) in this study. Therefore, the coefficient of this variable is expected to appear with a negative sign.

The Producer Support Estimate (PSE_t) is the variable used in this study for measurement of agricultural support in Brazil. It is an indicator of the annual monetary value of gross transfers from consumers and taxpayers to support agricultural producers, measured at the farm gate level, arising from policy measures, regardless of their nature, objectives or impacts on farm production or income (OECD, 2021). Government supports based on specific commodity outputs, input use, insurance payments, taxes and such would probably increase the quality and quantity of agricultural production and therefore exports. Hence, the coefficient on this variable is expected to be positive.

The total road length ($ROAD_t$) is the first variable to represent the domestic infrastructure change. It represents the road quantity consisting of total paved and non-paved road length in km. In developing countries like Brazil, infrastructure plays an important role in increasing agricultural productivity. Improvement of rural infrastructure stimulates growth in rural areas. It provides important connectivity with growing markets adjacent to rural areas and also decreases input and transaction costs (Llanto, 2012). It is expected that Brazilian agricultural exports increase as road quantity gets higher. Therefore, a positive relationship is predicted for this variable.

As the quantity of roads, the quality of the road ($ROADQ_t$) is another factor that reduces transportation costs. Improved road network quality is strongly associated with higher trade flows. Shepherd and Wilson (2008) stated that upgrading road networks could increase trade flows substantially by lowering transactions costs after examining the effect of road network quality on intra-regional trade of 138 cities in 27 countries from Europe and Central Asia. Brazilian policymakers have also given consideration to road quality as well as road quantity. It can be found logical to mention that increasing road quality network opens a door to increase agricultural trade since the products become easier to transport and more accessible to port facilities with lower transactions costs. In this study, to get the road network quality variable, the share of paved-way to total road network was simply taken for each year and added to the model. A positive relationship between paving the road and the export value is expected.

The third and last variable representing the domestic infrastructure change of Brazil is total railways length ($RAIL_t$). Besides highways, railways are also very important as far as transportation of agricultural commodities is concerned. Since 2013, railways have been the most used option (50% in 2019) for the transportation of corn and soybeans to the ports which are

Brazil’s most exported agricultural products (Anuário Estatístico de Transportes, 2020) (OEC, 2021). Therefore, a positive sign for the coefficient of the variable is expected.

Four distinct variables for changes in agricultural inputs of Brazil during the time are examined. The first one ($MACH_t$) represents the number of agricultural machineries sold a year. The sales covers combine harvesters, tillers, and tractors, imperative parts of modern agriculture. This variable is lagged by one year to provide a robust estimate of the effect since agricultural production is seasonal.

The second variable is Brazil's agricultural land share ($AGLAND_t$). It expresses the ratio of agricultural areas to the total area of the country. The amazon deforestation due to agricultural activities, which is also the subject of great debate in the literature, might be another factor behind the rise.

The other two inputs included are fertilizers ($lnFERT_t$) and pesticides ($lnPEST_t$). They are another important component of modern agriculture. The fertilizer variable covers the use of three primary nutrition (known as NPK): nitrogen (N), phosphate (P2O5), and potash K2O. The pesticide variable covers all major pesticide groups: insecticides, herbicides, fungicides, plant growth regulators, and rodenticides as well as relevant chemical families. It is expected that a rise in agricultural inputs would probably increase agricultural production and thereby agricultural exports. Thus, the coefficients of these four variables are anticipated to be positive.

Besides the agricultural land share of Brazil, a variable representing that of country j ($AGLAND_{jt}$) is added into the model to measure the effect of the demand-side supply change on the agricultural exports of Brazil. Koo et al. (2006), Erdem and Nazlioglu (2008), and Vieira and Reis (2019) are some examples that included the same variable in their studies. It would not be wrong to think that possible increases in the production of the importing countries will reduce the demand, which can be counterproductive for Brazilian agricultural export performance. Hence, a negative sign for this variable is expected.

Agriculture Producer Price Index (PPI_t) shows the average annual change over time in the selling prices received by Brazilian farmers. This price is measured at the farm gate, the point where the commodity leaves the farm and thereby does not incorporate the costs of transport and processing (FAO, 2021). Domestic prices can be perceived as a reflection of global prices. Mundlak and Larson (1992) found most of the variations in world prices of agricultural commodities are transmitted to domestic prices. It can also affect the internal demand, and therefore the export volume. Products with higher prices in the domestic market might be more subject to export. Esteves and Rua (2015) found a negative relationship between domestic demand and export performance in the short term. Therefore, an increase in the index is expected to result in a growth in the exports of Brazil.

The institutional quality index ($lnINSQ_t$) includes average rank of voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption for each year. Having stabile politics with an effective government and regulatory policy, less terrorism and corruption as well as a sound rule of law would probably have a positive effect on agricultural export. Thus, the sign of this variable is predicted to be positive as well.

The model includes two different trade openness-related variables. The Trade freedom index of the importing countries ($TRADEFREE_{jt}$) is a mixed measure of the absence of tariff and non-tariff barriers that affect imports and exports of goods and services (Heritage Foundation, 2021). Non-tariff barriers consist of restrictions on quantity, price, regulation, investment, customs, and direct government interventions. The input of tariff for the index is the tradeweighted average tariff rate which is a purely quantitative measure. As countries become more liberal with trade, they are predicted to trade more, so the coefficient of the variable is expected to be positive.

Preferential Trade Agreements (PTA_{jt}) is another important aspect to be considered in trade, which has been frequently used in the literature. It is stubborn fact political relations are a mixed picture for trade. Mutual trade agreements that worth billions of dollars, or imposing tariffs and its retaliations as an immediate punishment for disputes can directly influence trade volume between trading partners. Nevertheless, protectionist policies have faded away more and more with the formation of GATT, and bilateral relations between countries have increased and continued to be an important point for international trade. To examine this impact on Brazilian agricultural exports where it had signed 20 reciprocal trade agreements from the 83 sample, a binary variable (PTA_{jt}) representing the existence of a trade agreement between Brazil and its trade partner were included in the model. It is also expected to be positive since a trade agreement could have a positive impact on Brazilian agricultural export by reducing trade restrictions.

In addition to the variables stated above, there are some other variables excluded for this study. For instance, dummy variables representing colonial links in the history of two countries, as well as a common language, have been frequently used in the literature. Despite being in the dataset, these are not included since only one country (Portugal) has a colonial relationship with Brazil and speaks the same language. Furthermore, per capita GDP, which shows the income level of the countries, has been incorporated into some similar such as Sevela (2002) and Hatab et al. (2010). Even though this variable is also in the dataset, it is not used due to being collinear with GDP.

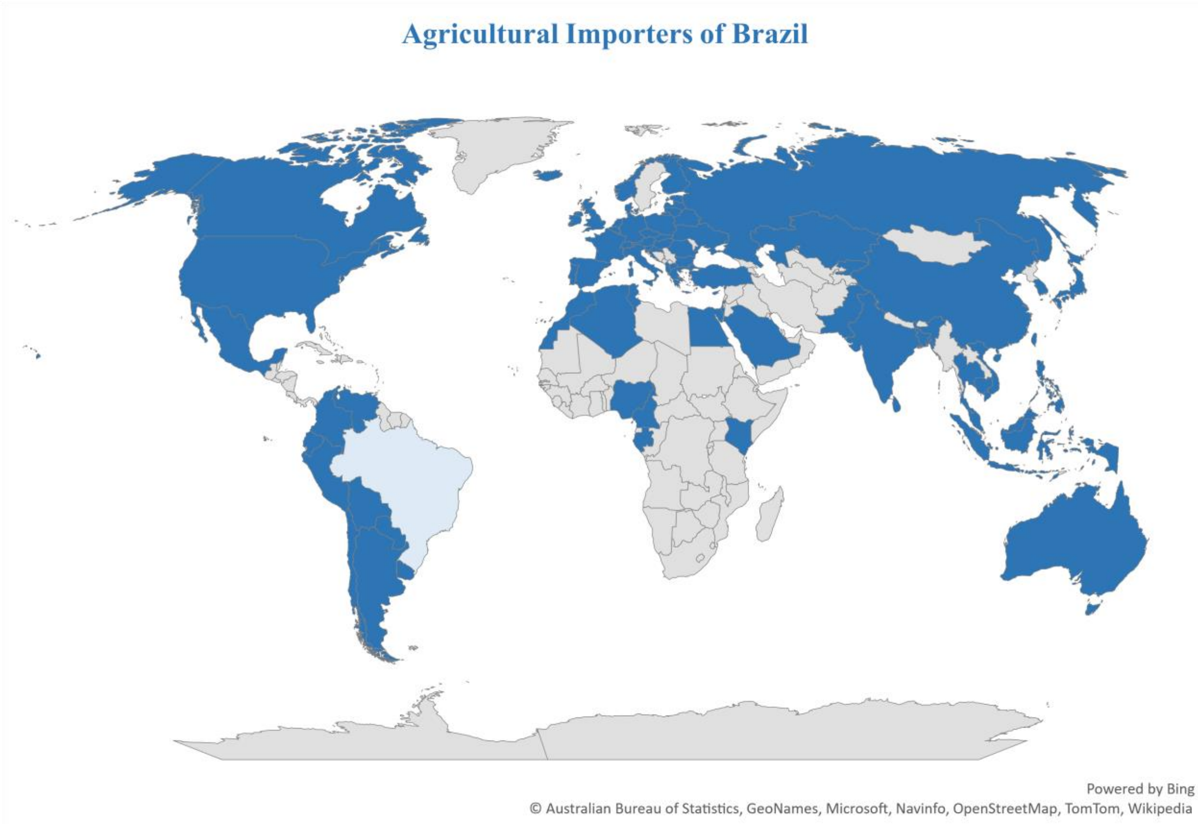
Table 3. Summary of hypothesis

Dependent Variable: Agricultural Export Performance of Brazil ($AGEX_{ijt}$)	
Independent Variable	**Expected Sign**
Real GDP of Brazil (GDP_t)	+
Real GDP of Imp. Country (GDP_t)	+
Distance ($DIST_j$)	-
Real Bilateral Exchange Rate ($BEXC_{jt}$)	-
Producer Support Estimate of Brazil (PSE_t)	+
Total Road Length in Brazil ($ROAD_t$)	+
Road Quality of Brazil ($ROADQ_t$)	+
Total Railways Length in Brazil ($RAIL_t$)	+
Technology Adoption of Brazil ($MACH_t$)	+
Ag. Land Share of Brazil ($AGLAND_t$)	+
Ag. Land Share of Imp. Country ($AGLAND_{jt}$)	-
Fertilizers Use of Brazil ($FERT_t$)	+
Pesticide Use of Brazil ($PEST_t$)	+
Ag. Producer Price Index (PPI_{it})	+
Institutional Quality Index of Brazil ($INSQ_{it}$)	+
Preferential Trade Agreements (PTA_{ijt})	+
Trade Freedom Index of Imp. Country ($TRADEFREE_{jt}$)	+
Adjacency (ADJ_j)	+
Ocean Inaccessibility of Imp. Country ($LANDLOC_j$)	-

4.3 Sample Size and Data

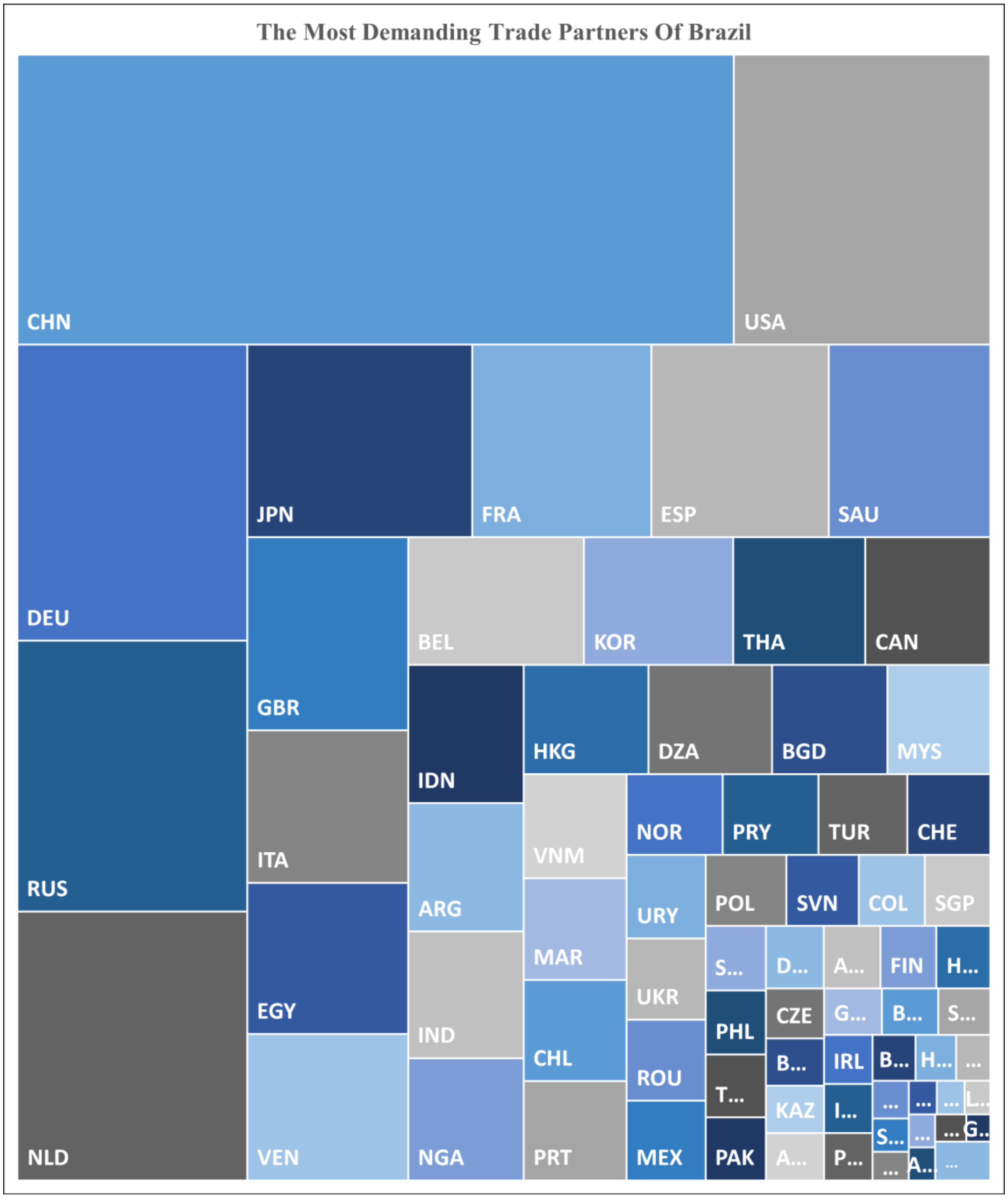
In this research, to analyze the Brazilian agricultural export, a gravity model in balanced panel data designed to cover agricultural exports from Brazil to its major 83 importing partners (36 European, 24 Asian, 12 South and North American, 9 African, and 2 Oceanian countries). The trading partners of Brazil were determined based on the availability of data, so all specific countries that import agricultural products from Brazil given in CEPI-CHELEM database were taken into this study. Figure 7 shows the selected 83 sample countries for this study.

Figure 7. The selected 83 sample countries



Because there was no separate data for Serbia and Montenegro before 2006, these two countries were examined as a single country. The explanatory variables of Serbia and Montenegro were handled by combining them after 2006. Since Serbia is a landlocked country, Podgorica, the capital of Montenegro, was taken as the basis for the distance variable, and the binary variable indicating whether or not a country is landlocked marked as 0. Another variable to be decided on for these two countries was the bilateral exchange rates since Montenegro started to use the euro after the separation. To maintain consistency, the Serbian dinar was taken as the national currency of these two countries.

Figure 8. The most demanding partners of Brazil from 1996-2018

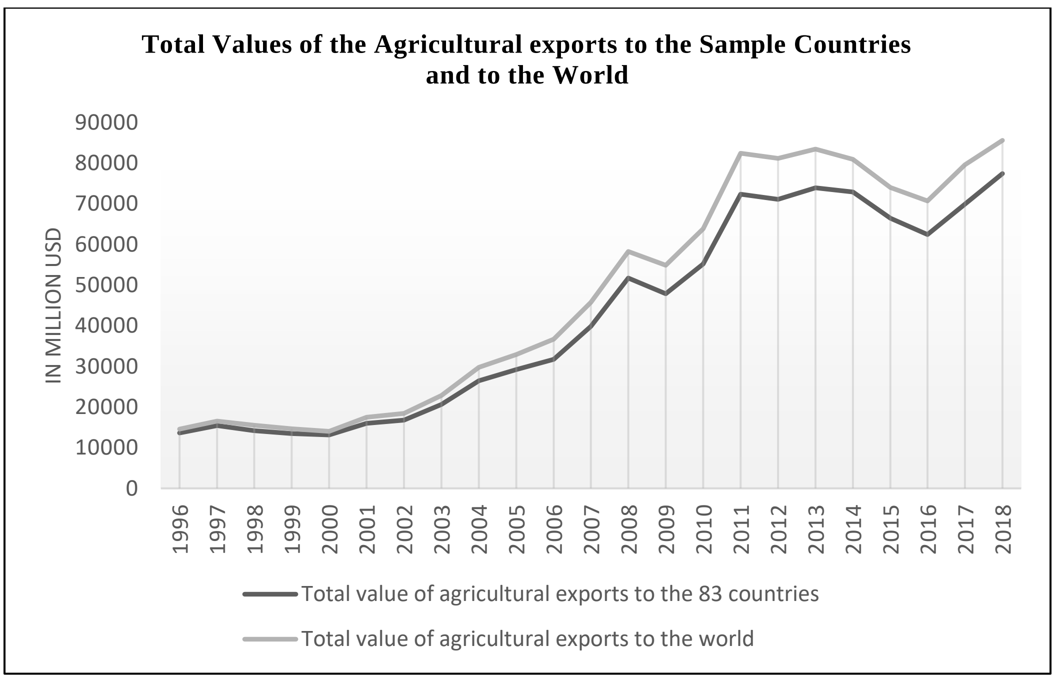


Data Source: CHELEM - International Trade Database

Figure 8 above shows the most importing countries in the 23-year period by sorted inflation-adjusted arithmetic mean. China alone has a share of around 19%, and around 47% of total value of Brazilian agricultural products comes from altogether China, the United States, Germany, Russia, the Netherlands, and Japan.

Since the dataset was created to the extent of data availability, this assessment does not include all of the nations that import agricultural products from Brazil over the period of 23 years. However, data of the 83 sample countries constitute around 90% of the agricultural export of Brazil to the whole world. Figure 9 displays the total value of the Brazilian exports to the selected countries and the whole world. As it can be easily seen, the dependent variable of this study exhibits the same trend with the total export value. The rapidly increasing export volume has maintained its overall momentum although the negative effect of the economic recessions on the export performance shows themselves.

Figure 9. How much the selected samples reflect total agricultural exports of Brazil



Data Source: CHELEM - International Trade Database

When we look closely at the trends of each country j's imported Brazilian agricultural products over the years (See Appendix C), relatively small countries exhibit more volatile trend like Kyrgyzstan, Luxemburg, and Estonia. We can also see that the import volume of three countries in the selected sample decreased during the period: Belarus, Bulgaria and Hungary, which are all from Europe. Moreover, some countries exhibit relatively increasing trend such as Vietnam, Venezuela, Gabon, Ecuador, Albania.

Considering the changes in the political and economic structures of the countries over time, particularly with the division of Yugoslavia and the Soviet Union, the data were collected from 1996 to 2018, for a period of 23 years, which made the panel data balanced. All measurements are annual. Since the study focuses on just agricultural export rather than bilateral flows, only the export data for Brazil were used.

The agricultural exports were taken as one category, and AL (R02 industry) code from Cepii-Chelem Sectoral Classification was considered. It includes cereals (JA), edible agricultural products (JB), non-edible agricultural products (JC), cereal products (KA), fats of vegetable or animal origin (KB), meat and fish (KC), preserved meat and fish products (KD), preserved fruit and vegetable products (KE), sugar products (KF), animal foodstuffs (KG), beverages (KH) and manufactured tobaccos (KI).

Data for the independent variables came from a variety of sources. Data on Gross Domestic Products (GDP_t,GDP_{jt}) were taken from World Bank's World Development Indicators (WDI), and data on Producer Support Estimate (PSE_t) were obtained from the PSE database of OECD. The monetary value of these variables was converted from nominal to real ones using GDP price deflator of Brazil based on 2010 prices again. The distance ($DIST_j$) as the crow flies between Brasilia (the capital city of Brazil) and the capital cities of the importing countries was taken in km from freemaptools.com. Data on agricultural land share of Brazil and country j ($AGLAND_t$, $AGLAND_{jt}$), fertilizer and pesticide use in Brazil ($FERT_t$, $PEST_t$), and Brazilian agricultural producers price index (PPI_t) were obtained from FAO's FAOSTAT database. Information about adjacency (ADJ_j) and existence of preferential trade agreements (PTA_{jt}) between Brazil and its partner was sourced from the CEPII-CHELEM database again. Information about the existence of countries' ports ($LANDLOC_j$) was taken from worldportsource.com. In addition to those commonly used trade data, data related to internal transportation costs ($ROAD_t$, $ROADQ_t$, $RAIL_t$) and technology-adoption ($MACH_t$) were provided from national sources of Brazil: the road and rail length were collected from several annual statistical reports of CNT and DNIT (from 1996 to 2019), and the annual number of sold agricultural machineries were from ANFAVEA's 2021 statistical yearbook. For the data on bilateral real effective exchange rates, a secondary data source was used (see Darvas, 2012). Finally, trade freedom index of country j was taken from the Heritage Foundation's Dataset, and institutional quality index of Brazil was obtained from World Bank's World Governance Indicators (WGI). Table 4 displays summary statistics for the variables used in this study.

Table 4. Summary statistics for the included variables

Variable	# of Obs.	Unit	Mean	Std. dev.	Min	Max
agexjt	1.909	USD (Constant 2010)	7085890	1,83E+07	56,14407	3,89E+08
gdpt	1.886	USD (Constant 2010)	1,93E+12	3,57E+11	1,41E+12	2,42E+12
gdpjt	1.882	USD (Constant 2010)	6,92E+11	1,87E+12	2,61E+09	1,80E+13
distj	1.909	Km	10189,59	4163,193	1463,434	18832,29
bexcjt	1.909	Per 1 Br. Real	297,1114	2659,265	0,0013163	106340,4
pset	1.909	USD (Constant 2010)	1,54E+08	6,58E+07	21191,15	2,41E+08
roadt	1.909	Km	1608383	50829,57	1561450	1724938
roadqt	1.909	Percentage	0,1208604	0,0169938	0,0899299	0,1383722
railt	1.909	Km	29616,65	537,1135	28874	30621
macht	1.909	Level	40961,13	16745,81	12431	77594
aglandt	1.909	Percentage	27,6513	0,3715025	27,27	28,34
aglandjt	1.892	Percentage	40,2711	20,84476	0,93	85,49
fertt	1.909	Tonnes	1,02E+07	3400559	5020000	1,64E+07
pestt	1.909	Tonnes	260779	103257,1	101622	395646
ppit	1.909	Index	57,03609	28,49551	21	105,81
insqt	1.909	Index	52,01618	4,096387	42,1788	58,23399
tradefreejt	1.866	Index	74,32586	13,76057	0	95
ptaijt	1.909	Binary	0,2346778	0,4239083	0	1
adjj	1.909	Binary	0,0843373	0,2779659	0	1
landlocj	1.909	Binary	0,0722892	0,2590339	0	1

4.4 Analytical Approach

In gravity models, cross-sectional data has been frequently used. However, on the cross-sectional section estimation, there is a possibility of selecting a non-representative year and individual effects that are specific to a given country cannot be tracked. Hence, the modern approach is to use panel data (Egger, 2002).

The panel data enables monitoring of the individual effects that cannot be identified like cultural factors among the trading partners. It also avoids the risk of selecting a year that is not representative (Yaffee, 2003). There are two methods of estimating the individual effects on the panel data that cannot be observed: the model for fixed effects (FE) and the model for random effects (RE). Another technique to use to analyze panel data is pooled Ordinary Least Squares (OLS). However, it does not account for importer variation. It makes no country-specific estimates and assumes that all countries are homogeneous.

The FE and RE models differ from each other by the treatment of individual-specific impacts. In the FE model, it is believed that the individual-specific effects are correlated with the individual variables. Thus, there is no omitted variable bias since it is assumed it correlates with the ones in the model. A drawback of the FE models is that they cannot be utilized to examine time-invariant causes of dependent variables. Technically, the individuals' time-invariant features are perfectly collinear with the entities (Kohler and Kreuter, 2005). For instance, all geography-related variables in this study are time-invariant. Physical distance between capital cities, adjacency and being landlocked do not change over time. Therefore, those independent variables cannot be estimated by the FE model since it removes them to examine the net impact of the explanatory variables on Brazilian agricultural export performance.

On the other hand, in the RE model, the individual-specific effects are assumed to be not correlated with predictors, and therefore there are changes over time within one group that the variables in the model cannot explain. Contrary to the FE model, the biggest disadvantage of the random-effects approach is the problem of bias introduced by partial pooling in estimates of β (Clark and Linzer, 2012). The strong assumption of no correlation between the individual-specific effect and predictors can also be harder to justify, especially where causal inference is the goal (Townsend et al., 2013).

The Hausman specification test is consulted on the panel data analysis with the aim of determining which one is to be used among the FE or RE models (Yaffee, 2003). It simply compares the estimators whether both are consistent or not. If the null hypothesis of no correlation between the individual effects and the regressors is rejected, which means there are differences between the estimators, then the FE is used since it implies that the FE is more efficient than the RE.

Before performing the Hausman specification test to determine between the FE and RE, the Breusch-Pagan Lagrange Multiplier Test for Random Effects was employed to ensure that there is a significant difference across countries (panel effect) present. Following the application of the Breusch-Pagan LM Test, the null hypothesis of no variance across entities was rejected and therefore it was concluded that the pooled OLS regression is not appropriate (see Appendix A1).

The resulting chi^2 value of 53 (82 with the sigmamore option) was enough for the Hausman test statistic to reject the null hypothesis that individual effects and regressor are not correlated. That implies that the FE is more efficient than the RE to assess the factors affecting Brazilian agricultural exports to its main trade partners. The resulting test statistic is significant at the 99% level (see Appendix A3).

After determining that the FE model is the most suitable model for this study, a Wald test was employed to see whether or not time-fixed effects are needed when running the FE model. That is a joint test to see if the dummies for all years are equal to 0, if they are, then time-fixed effects are not needed (Torres-Reyna, 2007). The p-value for the test is found 0.13 which is bigger than 0.05, so it is a failure to reject the null hypothesis that the coefficients for the 23 years from 1996 to 2018 are jointly equal to zero. Therefore, time-fixed effects are not needed for this study (see Appendix A5). Thus, the FE regression (within estimator) utilized to reveal Brazil's agricultural export determinants is as follows:

$$Y_{jt} = \beta_1 x_{1,jt} + \cdots + \beta_k x_{k,jt} + \alpha_j + u_{jt} \text{ (4)}$$

where: α_j is equal to β_0+Z_j (individual-specific effect). Taking the average across t and reorganizing it:

$$\frac{1}{T} * \sum_{t=1}^{T} Y_{jt} = \beta_1 * \frac{1}{T} * \sum_{t=1}^{T} X_{1,jt} + \cdots + \beta_k * \frac{1}{T} * \sum_{t=1}^{T} X_{k,jt} + \frac{1}{T} * \sum_{t=1}^{T} \alpha_j + \frac{1}{T} * \sum_{t=1}^{T} u_{jt} \text{ (5)}$$

we have:

$$\bar{Y}_{jt} = \beta_1 \bar{X}_{1,j} + \cdots + \beta_k \bar{X}_{k,j} + \alpha_j + \bar{u}_{jt} \text{ (6)}$$

Subtracting equation (6) from equation (4), we have the entity-demeaned (within) estimator:

$$Y_{jt} - \bar{Y}_{jt} = \left(\beta_1 x_{1,jt} - \beta_1 \bar{X}_{1,j}\right) + \cdots + \left(\beta_k x_{1,jt} - \beta_k \bar{X}_{k,j}\right) + \left(\alpha_j - \alpha_j\right) + u_{jt} - \bar{u}_j \text{ (7)}$$

Specifying the equation (7) for Brazil, we lastly have – recall equation (3):

$$lnAgex_{jt} - \overline{lnAgex}_j = \left(\beta_1 lnGDP_t - \beta_1 \overline{lnGDP}\right) + \left(\beta_1 lnGDP_{jt} - \overline{lnGDP_j}\right) + \cdots +$$

$$\left(\beta_{19} LANDLOC_j - \beta_{19} \overline{LANDLOC_j}\right) + \left(\alpha_j - \alpha_j\right) + u_{jt} - \bar{u}_j \text{ (8)}$$

In equation 8 above, the country-specific effect (α_j) and the last regressor ($LANDLOC_j$) cancel out when the regression is estimated due to being fixed over time just like the other two time-invariant variables ($DIST_j$ and ADJ_j).

Furthermore, in order to test for heteroskedasticity as is often the case with cross-sectional data, the Modified Wald test for groupwise heteroskedasticity in the fixed effect regression model was applied. The null hypothesis of homoskedasticity is rejected, which implies the presence of heteroskedasticity (see Appendix A9).

Another concern about panel data analyses is serial correlation since panel data includes time series as well as cross-sectional data. It causes the standard errors of the variable coefficients to be smaller than they actually are and also causes the R2 to be higher than they are (Torres-Reyna, 2007). In such cases, serial correlation causes inefficient estimates and biased standard errors. The Wooldridge Test for autocorrelation in panel data was performed to check the presence of serial correlation. With a rejection of the null hypothesis, it was concluded that serial correlation was the second problem of the estimation phase of the study after heteroskedasticity (see Appendix A11).

In order to overcome the heteroskedasticity and serial correlation problems, the FE was run with robust and partner clustered standard errors in this study as well as the other estimation techniques. Robust and clustered standard errors accommodate for both heteroskedasticity and autocorrelation. (Cameron and Trivedi, 2010). Nonetheless, for comparing the different results, Feasible Generalized Least Squares (FGLS) was performed and added to Appendices part (see Appendix A13).

Cross-sectional dependence correlation is another aspect that needs to be dealt with to get robust estimation results if a macro panel with long time series is had in hand. They can exhibit widespread cross-sectional dependence, in which all units in the same cross-section are correlated. This is frequently attributed to the action of some unobserved common factors that are shared by all units and affect them all, albeit in different ways (Born and Breitung, 2016). However, this is not much of a problem in micro panels with higher entities and few time periods (Baltagi, 2008). Pesaran, Frees, Friedman, and Breuch-Pagan LM Independence tests were applied to ensure there is no cross-sectional dependence correlation. Since this study has large N and small T, no test results were obtained (see Appendix A7).

The model of this study includes a total of 19 factors as discussed in section 4.2 due to considering a variety of perspectives to explain the agricultural exports growth of Brazil. Pouring such a lot of variables into the model increases the chances of multicollinearity and lowers the statistical power of the model. Also, it could cause an overfitting problem, which misleads the coefficients, R-squared, and p-values especially when the sample size is small. Moreover, the absolute majority of these variables are Brazil-specific that changes over time but not over country j: GDP_t, PSE_t, $ROAD_t$, $ROADQ_t$, $RAIL_t$, $MACH_t$, $AGLAND_t$, $FERT_t$, $PEST_t$, $INSQ_t$, PPI_t. The same repeated data for each sample country from 1996 to 2018 reduces the model sensitivity.

One of the ways for a better fit model is reducing the number of included variables. Some of the six dimensions considered in this study contain more than one only-time-variant variable. For example, three different variables ($ROAD_t$, $ROADQ_t$, $RAIL_t$) are included to examine the impact of changes in domestic infrastructure, or four different variables ($MACH_{it}$, $AGLAND_{it}$, $FERT_{it}$, $PEST_{it}$) for the changes in agricultural inputs in Brazil. Those similar factors could be combined and turned into a single one. Also, dropping the variables that are not crucial for the model is another option. Principal component analysis (PCA) could be applied to identify patterns in data and reduce the number of variables without losing the variation of the dataset as much as possible. Lastly, without dropping any variable, similar factors could also be grouped based on the dimensions examined in this Brazilian case, and several different models can be obtained by analyzing each group with the baseline gravity model. The obtained results from the models would be interpreted comparingly to a common one as well.

To address this issue and increase the statistical power of the model, the number of variables were reduced to 11 by regarding correlation matrix and exploratory factor analyses result (see Appendix B1 and B2). Being out of this study's research objectives, $AGLAND_{jt}$ was not included in the new reduced model. All time-invariant variables ($DIST_j$, ADJ_j, $LANDLOC_j$) were dropped out since the FE model does not examine them. $ROADQ_t$, $FERT_t$, $PEST_t$, and PPI_t were also omitted because of being collinear with other predictors and having low unique variances. The same diagnostic tests were also applied to the parsimonious model (See Appendix A2, A4, A6, A8, A10, A12). Because cross-sectional dependence was determined as a result of applied Pesaran Test (see Appendix A8), the FE with Driscoll and Kraay (1998) standard errors was performed for the reduced model as well. The estimator proposed by Driscoll and Kraay (1998) generates standard errors that are robust to heteroskedasticity, spatial correlation (cross sectional dependence), and autocorrelation (Hoechle, 2007).

Terminally, for more convenient interpretation of the estimated parameters, the logarithmic form of the variables that has large numbers was used in the models. Since both dependent and independent variables are log-transformed (double-log), the interpretation is more convenient because the coefficients show first-hand respective elasticities. The logarithmic form also curbs the impact of extreme observations and outliers in the dataset, so the distribution of observations is better behaved (Wooldridge, 2015).

5. RESULTS

Table 5 below shows the findings of equation 3, which was created to find an answer to the question of what variables have influenced Brazil's remarkable development in agricultural exports. As described in the previous chapter, the major disadvantage of the equation is that it involves several variables, which can mislead the significance and magnitude of the coefficients. In order to address this issue, a parsimonious model was developed by excluding problematic factors as well as time-invariant ones that the FE cannot anticipate. The outcome of the parsimonious model regression is in model 6, where the interpretations will be concentrated. In addition to model 6, the table exhibits the result of basic OLS (Model 1) for the conventional gravity model, pooled OLS (model 2), RE (model 3), a second RE without collinear variables (model 4), and a second FE model with Driscoll and Kraay standard errors with all original variables of the study.

All models shown in table 5 are statistically significant at the level %1 with the p-value of 0.00. There is a considerable extent increase in within adjusted R2 value of the parsimonious model compared to model 5.

Baseline model estimations given in model 1 shows that the results are consistent with theoretical framework of the gravity model of trade. It is likely to find in the agricultural trade literature that importer’s economic size is more important than exporter’s economic size and the distance is usually negative with appearing around 1.

Table 5. Results for Brazilian agricultural exports to its trade partners

lnAGEXijt	Model 1 Basic OLS	Model 2 OLS	Model 3 RE	Model 4 RE-2	Model 5 FE D-K	Model 6 FE-2 D-K
lnGDPit	**.733***** (.157)	-1.37 (1.28)	**-1.6***** (.501)	**.26***** (.094)	**-1.24**** (.530)	**.26***** (.680)
lnGDPjt	**.913***** (.017)	**.86***** (.016)	**.98***** (.085)	**.91 ***** (.090)	**1.79***** (.087)	**.94***** (.049)
lnDISTij	**-.679***** (.056)	**-.29***** (.080)	-.323 (.343)	-.467 (.349)	omitted	
lnBECXijt		.006 (.012)	.009 (.059)	.023 (.060)	**-.14***** (.039)	.0002 (0.304)
lnPSEijt		-.015 (.043)	-.014 (.016)	.006 (.007)	-.011 (.013)	.0064 (.0056)
lnROADit		-2.4 (2.2)	**-2.55***** (.797)	**.89*** (.504)	**-2.4**** (1.08)	**.76**** (.357)
ROADQit		7.0 (12.4)	**6.21*** (3.30)		3.244 (5.881)	
lnRAILit		-2.42 (4.89)	**-2.99*** (1.74)	**2.6**** (1.09)	-1.737 (1.942)	**2.45*** (1.275)
laglnMACHit		-.052 (.24)	-.058 (.079)	**.19***** (.073)	-.014 (.079)	**.19*** (.106)
AGLANDit		**-1.23**** (.60)	**-1.47***** (.24)	**-.406**** (.161)	**-1.43***** (.204)	**-.42**** (.154)
AGLANDjt		**.005***** (.001)	**.020**** (.008)		**.038***** (.007)	
lnFERTit		.106 (.319)	.108 (.132)		.080 (.146)	
lnPESTit		.643 (.588)	**.521**** (.239)		.342 (.328)	
PPIit		.018 (.012)	**.02***** (.004)		**.016**** (.006)	
INSQit		.027 (.023)	**.024***** (.009)	-.002 (.009)	**.023***** (.007)	-.002 (.009)
TRADEFREjt		**-.012***** (.003)	**.004*** (.006)	.001 (.005)	.001 (.002)	.002 (.002)
PTAit		.031 (.072)	**.35**** (.139)	**.425*** (.230)	.288 (.177)	**.507***** (.162)
ADJij		**.479***** (.149)	.264 (.578)	.097 (.627)	omitted	
LANDLOCjt		**-.640***** (.228)	-.647 (1.001)	-.386 (.907)	omitted	
Constant	**-24***** (4,55)	**116**** (55.6)	**133***** (27.16)	**-36***** (10.8)	**86***** (14.67)	**-38***** (12.4)
Adj R2	.6078 (Overall)	.6402 (Overall)	.6167 (Overall)	0.6427 (Overall)	0.3586 (Within)	0.5406 (Within)
# of Obs.	1882	1744	1744	1865	1744	1865

Note: Robust standard errors are in parenthesis (Model 5 and 6: Driscoll-Kraay standard errors)
***/**/* shows statistically significant coefficients at %1, %5, %10 level, respectively.

The obtained results for GDP of Brazil and recipient countries (GDP_t and GDP_{jt}), total road and railways length ($ROAD_t$ and $RAIL_t$), sold agricultural machinery ($MACH_t$), and existing trade agreement between trading partners (PTA_{jt}) are in line with their hypothesis. Improvement in domestic transportation infrastructure, increasing economic size of Brazil and its trading partner, farming automation, and signing trade agreements promote Brazilian agricultural exports.

Brazil's economic size, which represents the production capacity in theory, is one of the sources for the expansion in agro-exports. Holding constant all other factors, a one-point increase in Brazil's GDP will increase its agricultural export performance by 0.26%.

The coefficient of foreign GDP is also positive and statistically significant at the level 1% as in prior relevant studies. The number of studies in the literature in which such case has not been encountered is quite small. This result implies that the value of Brazilian agricultural exports will rise roughly 1% to its particular trading partner as the market size of the partner goes up one percentage point. The magnitude of the coefficient is noticeable when compared with relevant studies. For instance, the coefficient in the studies agro-export of Pakistan (Atif et al., 2008) and Albania (Braha et al., 2017) were obtained 0.35 and 0.75, respectively. Consideringly, the role of foreign demand plays an important role for Brazilian agro-export.

Brazil's effort to improve its transportation infrastructure is another promoter for the boom. Both $ROAD_t$ and $RAIL_t$ are positive and statistically significant. With a coefficient of 2.45, railways seem more important means of transport for Brazilian agricultural logistics. It implies that a one percent increase in the railway network will result in an increase of 2.45% in Brazilian agricultural exports.

As expected, more automated agriculture is another contributing factor to the phenomenal growth. A percent increase in participation of machinery to agricultural production will increase the exports by around 0.2%.

The obtained coefficient for PTA_{jt} is statistically significant at the level 1% and positive. The result shows that a signed agreement between Brazil and its trading partner could increase agricultural exports volume of Brazil. The finding is in line with many investigations on agricultural trade like Cipollina and Salvatici (2010). They examined 85 different studies (mostly gravity-type) using a meta-analysis approach in order to find the "true" effect of trade agreements. After analyzing FE and RE regression results existing in the literature, they confirmed a robust and positive impact of trade agreements on trade volume around 11% increase.

On the other hand, contrary to what is expected, the increase in new areas that Brazil has added to agricultural production mainly from the Amazon rainforest, which has been deforested for cattle ranching and soybean production, has a negative effect on the export flow of Brazil. This may be attributed to that the land use towards amazon deforestation has usually belonged to small farmers whose market access is relatively low when compared to big farmers. Brondizio et al. (2009) stated that though they have a fraction of the total deforested area, small farmers have contributed to the majority of deforestation events at the regional level.

The variable for the currency depreciation that Brazil has been experiencing ($BEXC_{jt}$) was found statistically insignificant although it appears significant and as expected in model 5. Given this, it might not be accurate to say that Brazil has gained for the phenomenal export growth from softening Brazilian Real. Also, agricultural support of Brazil (PSE_t), institutional quality of Brazil ($INSQ_t$), and trade openness index of recipient countries (TRADEFREEjt) were obtained statistically insignificant in model 6.

6. CONCLUSION

With a rapid rise in agricultural exports, Brazil has become an agricultural superpower and the largest competitor of the United States. It is now the biggest supplier of soybean, corn, and poultry products in the global market, having surpassed the United States market share over the last two decades (OEC, 2021).

In addition to its geographical advantage suitable for agriculture, a relatively liberal economy and government policies to strengthen the agriculture sector have boosted the agro-export of Brazil. There have been significant attempts to improve foreign relations, domestic infrastructure, particularly in regions where agricultural activities are abundant, a more automated sector with more farmland and government incentives as well as the economic crisis and currency depreciation.

This study examined the factors behind the remarkable growth of Brazilian agricultural exports with a gravity model, covering 83 importing partners from 1996 to 2018. The goal of this work is, in particular, to explain the phenomenon by considering six different points as well as traditional gravity model factors: macroeconomic policies (supportive agricultural policies and trade policies), institutional quality, currency depreciation, domestic infrastructure change (road and railways), changes in agricultural inputs (land-use, technology adoption as well as traditional ones), and domestic output prices.

The result shows that improvements in domestic transportation infrastructure, more mechanized agriculture, and more liberal foreign policies promote Brazilian agricultural exports. Furthermore, the growing economic size of Brazil and its trading partner increase the trade flow. On the other hand, the empirical analysis yields a surprising result; Brazil’s increasing farmland has a negative impact on its agricultural export performance.

Based on the findings above, some suggestions can be drawn to increase the export performance of Brazil. First, the government should expedite its effort to build more diplomatic relations and take part in more trade agreements in the international area, especially with large market size countries. Second, the Brazilian government should encourage more professional and efficient production, particularly through increased mechanization rather than expanding agricultural land. In this context, it would be reasonable to increase the strict environmental policies that will minimize the deforestation of Amazon and to look for possible ways of a transition to more automated production of small farmers. Third, public and private investments to improve internal transportation infrastructure should be continued on the basis of easy market access and low transportation costs of producers.

The results obtained from the gravity model might be useful not only for Brazilian policymakers but also for its competitors in the global market. The study could be further studied with more disaggregated data by targeting a specific product or policy, which may give different results.

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APPENDICES

Appendix A. Test Results

Appendix A1. The Breusch-Pagan Lagrange Multiplier Test for Random Effects Result (Original Model)

```
Breusch and Pagan Lagrangian multiplier test for random effects

        lnragexijt[partner,t] = Xb + u[partner] + e[partner,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
               lnragex~t |    3.80776       1.951348
                       e |   .3915609       .6257483
                       u |   .8865093       .9415462

        Test:   Var(u) = 0
                             chibar2(01) =  7564.04
                          Prob > chibar2 =   0.0000
```

Appendix A2. The Breusch-Pagan Lagrange Multiplier Test for Random Effects Result (Parsimonious model)

```
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

        lnagexijt[partner,t] = Xb + u[partner] + e[partner,t]

        Estimated results:
                         |       Var     SD = sqrt(Var)
                ---------+-----------------------------
               lnagexijt |   4.037186       2.009275
                       e |   .4234371       .6507204
                       u |    1.05957       1.029354

        Test: Var(u) = 0
                             chibar2(01) =  9644.59
                          Prob > chibar2 =   0.0000
```

Appendix A3. The Hausman Specification Test Result (Original Model)

	Coefficients (b) fe	Coefficients (B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
lnrgdpit	-1.242062	-1.59578	.3537174	.
lnrgdpjt	1.789068	.9804081	.8086599	.1287976
lnbexcijt	-.1400764	.0091326	-.1492089	.0348781
lnvrpseit	-.0105551	-.0136434	.0030883	.
lntroadit	-2.397545	-2.548196	.1506512	.
roadqit	3.243819	6.209744	-2.965925	.
lnrailit	-1.737262	-2.986481	1.249219	.
laglnmachit	-.0144145	-.0575911	.0431766	.
aglandit	-1.426283	-1.46634	.0400576	.
aglandjt	.0383426	.020266	.0180765	.0053976
lnfertit	.0799993	.1084468	-.0284474	.
lnpestit	.3423648	.5207839	-.1784192	.
ppiit	.0158813	.0210198	-.0051384	.
insqit	.0234305	.0244287	-.0009982	.
tradefreejt	.0011895	.004247	-.0030575	.0005776
ptaijt	.2882805	.3486408	-.0603603	.1029581

b = Consistent under H0 and Ha; obtained from **xtreg**.
B = Inconsistent under Ha, efficient under H0; obtained from **xtreg**.

Test of H0: Difference in coefficients not systematic

```
   chi2(15) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            =  53.21
Prob > chi2 = 0.0000
(V_b-V_B is not positive definite)
```

Appendix A4. The Hausman Specification Test Result (Parsimonious model)

```
. hausman fe re

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |      fe           re          Difference       Std. err.
-------------+----------------------------------------------------------------
     lngdpit |    .2606054     .2608186       -.0002132        .0184326
     lngdpjt |      .94109     .9077333        .0333567        .0491394
   lnbexcijt |     .000202     .0195925       -.0193905        .0200133
     lnpseit |    .0063641     .0063219        .0000422               .
    lnroadit |     .763981     .8823724       -.1183914        .0721951
    lnrailit |    2.453314     2.578721       -.1254074               .
 laglnmachit |    .1861064     .1903405       -.0042341               .
    aglandit |   -.4239097    -.4068401       -.0170696               .
      insqit |   -.0016254    -.0015023       -.0001231               .
 tradefreejt |    .0023907     .0014656        .0009251        .0006788
      ptaijt |    .5067659     .5433379        -.036572        .1003049
------------------------------------------------------------------------------
                          b = Consistent under H0 and Ha; obtained from xtreg.
           B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

   chi2(11) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            =   6.09
Prob > chi2 = 0.8670
(V_b-V_B is not positive definite)

.
```

Appendix A5. Testparm Command Result (Original model)

```
( 1)  1997.year = 0
( 2)  1998.year = 0
( 3)  1999.year = 0
( 4)  2000.year = 0
( 5)  2001.year = 0
( 6)  2002.year = 0
( 7)  2003.year = 0
( 8)  2004.year = 0
( 9)  2005.year = 0
(10)  2006.year = 0

      F( 10,  1636) =    1.49
           Prob > F =    0.1383
```

Appendix A6. Testparm Command Result (Parsimonious model)

```
. testparm i.year

 ( 1)  1997.year = 0
 ( 2)  1998.year = 0
 ( 3)  1999.year = 0
 ( 4)  2000.year = 0
 ( 5)  2001.year = 0
 ( 6)  2002.year = 0
 ( 7)  2003.year = 0
 ( 8)  2004.year = 0
 ( 9)  2005.year = 0
 (10)  2006.year = 0
 (11)  2007.year = 0
 (12)  2008.year = 0
 (13)  2009.year = 0
 (14)  2010.year = 0
 (15)  2011.year = 0

       F( 15,  1756) =    1.65
            Prob > F =    0.0538
```

Appendix A7. Tests of Cross-Sectional Dependence Results (Original model)

```
. xtcsd, friedman

There are not enough common observations to perform Frees or Friedmand tests

. xtcsd, frees

There are not enough common observations to perform Frees or Friedmand tests

. xtcsd, pesaran

Error: The panel is highly unbalanced.
Not enough common observations across panel to perform Pesaran's test.
insufficient observations
```

Appendix A8. Test of Cross-Sectional Dependence Result (Parsimonious model)

```
. xtcsd, pesaran abs

Pesaran's test of cross sectional dindepen ence7=      .550, Pr = 0.0000

Average absolute value of the off-diagonal elements =     0.366
```

Appendix A9. Modified Wald Test Result (Original Model)

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (82)  =   40270.94
Prob>chi2 =      0.0000
```

Appendix A10. Modified Wald Test Result (Parsimonious model)

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (83)  =   63440.13
Prob>chi2 =      0.0000
```

Appendix A11. The Wooldridge Test Result (Original Model)

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      80) =     22.198
           Prob > F =      0.0000
```

Appendix A12. The Wooldridge Test Result (Parsimonious model)

```
Wooldridge test for autocorrelation in panel data
H0: no first order autocorrelation
    F(  1,      82) =     25.574
           Prob > F =      0.0000
```

Appendix A13. FGLS Regression Result (Original Model)

```
Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        homoskedastic
Correlation:   no autocorrelation

Estimated covariances      =         1          Number of obs     =      1,744
Estimated autocorrelations =         0          Number of groups  =         82
Estimated coefficients     =        20          Obs per group:
                                                              min =          2
                                                              avg =   21.26829
                                                              max =         22
                                                Wald chi2(19)     =    3102.88
Log likelihood             = -2723.338          Prob > chi2       =     0.0000
```

lnragexijt	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
lnrgdpit	-1.366471	1.273204	-1.07	0.283	-3.861906	1.128963
lnrgdpjt	.8621877	.0179462	48.04	0.000	.8270139	.8973616
lndistij	-.2863157	.0848632	-3.37	0.001	-.4526445	-.119987
lnbexcijt	.0063421	.0117902	0.54	0.591	-.0167663	.0294505
lnvrpseit	-.015458	.0428766	-0.36	0.718	-.0994946	.0685786
lntroadit	-2.428338	2.196373	-1.11	0.269	-6.733151	1.876475
roadqit	7.0032	12.33889	0.57	0.570	-17.18059	31.18699
lnrailit	-2.418109	4.94157	-0.49	0.625	-12.10341	7.26719
laglnmachit	-.0518384	.2401211	-0.22	0.829	-.5224672	.4187904
aglandit	-1.234451	.6198549	-1.99	0.046	-2.449344	-.0195578
aglandjt	.005234	.0014182	3.69	0.000	.0024543	.0080137
lnfertit	.1064353	.32695	0.33	0.745	-.5343749	.7472455
lnpestit	.6426882	.5705977	1.13	0.260	-.4756627	1.761039
ppiit	.0180727	.0123769	1.46	0.144	-.0061855	.0423309
insqit	.0273683	.0234743	1.17	0.244	-.0186405	.0733771
tradefreejt	-.0121031	.0025839	-4.68	0.000	-.0171674	-.0070387
ptaijt	.030507	.0816959	0.37	0.709	-.129614	.190628
adjij	.4792784	.1634248	2.93	0.003	.1589717	.7995851
landlocjt	-.6399088	.1213368	-5.27	0.000	-.8777244	-.4020931
_cons	115.665	57.12317	2.02	0.043	3.705642	227.6243

Appendix A14. FE with Driscoll-Kraay SEs Result

Regression with Driscoll-Kraay standard errors	Number of obs = 1744
Method: Fixed-effects regression	Number of groups = 82
Group variable (i): partner	F(16, 21) =8790619.84
maximum lag: 2	Prob > F = 0.0000
	within R-squared = 0.3586

lnragexijt	Coefficient	Drisc/Kraay std. err.	t	P>|t|	[95% conf.	interval]
lnrgdpit	-1.242062	.5298436	-2.34	0.029	-2.343932	-.1401924
lnrgdpjt	1.789068	.0869777	20.57	0.000	1.608188	1.969948
lndistij	9.417551	1.611405	5.84	0.000	6.066451	12.76865
lnbexcijt	-.1400764	.0386227	-3.63	0.002	-.2203967	-.0597561
lnvrpseit	-.0105551	.0128035	-0.82	0.419	-.0371814	.0160712
lntroadit	-2.397545	1.082758	-2.21	0.038	-4.649262	-.1458272
roadqit	3.24382	5.882068	0.55	0.587	-8.98861	15.47625
lnrailit	-1.737262	1.941681	-0.89	0.381	-5.775208	2.300684
laglnmachit	-.0144145	.0786354	-0.18	0.856	-.1779456	.1491167
aglandit	-1.426283	.2045478	-6.97	0.000	-1.851663	-1.000902
aglandjt	.0383426	.0070076	5.47	0.000	.0237694	.0529157
lnfertit	.0799994	.1462768	0.55	0.590	-.2241999	.3841986
lnpestit	.3423647	.3284046	1.04	0.309	-.3405901	1.02532
ppiit	.0158813	.0055765	2.85	0.010	.0042843	.0274783
insqit	.0234305	.0065177	3.59	0.002	.0098763	.0369847
tradefreejt	.0011895	.00225	0.53	0.603	-.0034897	.0058687
ptaijt	.2882805	.1770589	1.63	0.118	-.0799335	.6564946
adjij	0	(omitted)				
landlocjt	0	(omitted)				
_cons	0	(omitted)				

Appendix B. More on Data

Appendix B1. Correlation Matrix

	gdpit	gdpjt	distij	bexcijt	roadit	roadqit	railit	machit	aglandit	aglandjt
gdpit	1.0000									
gdpjt	0.1017	1.0000								
distij	0.0057	0.0443	1.0000							
bexcijt	0.0200	-0.0269	0.0478	1.0000						
roadit	0.7610	0.0954	0.0074	0.0142	1.0000					
roadqit	0.7746	0.0974	0.0074	0.0146	0.9920	1.0000				
railit	0.8024	0.0922	0.0063	0.0352	0.5923	0.6184	1.0000			
machit	0.8089	0.0805	0.0046	0.0071	0.6608	0.6825	0.5109	1.0000		
aglandit	0.8267	0.1036	0.0095	0.0348	0.7090	0.7435	0.8375	0.6253	1.0000	
aglandjt	-0.0150	0.0371	-0.1494	-0.0479	-0.0169	-0.0176	-0.0161	-0.0101	-0.0177	1.0000
fertit	0.8023	0.1027	0.0089	0.0332	0.8100	0.8334	0.7070	0.6876	0.8947	-0.0179
pestit	0.8909	0.1072	0.0080	0.0211	0.9267	0.9391	0.7974	0.7539	0.8872	-0.0180
ppiit	0.8321	0.1053	0.0094	0.0244	0.7863	0.8200	0.8132	0.6801	0.9782	-0.0185
insqit	-0.3791	-0.0679	-0.0067	-0.0449	-0.4724	-0.4798	-0.5990	0.0333	-0.6538	0.0152
tradefreejt	0.4087	0.1365	0.0174	-0.0741	0.4086	0.4152	0.3581	0.3610	0.4035	-0.1214
ptaijt	-0.0057	-0.1048	-0.3062	0.0316	-0.0120	-0.0115	-0.0039	-0.0080	-0.0063	0.0218
adjij	-0.0029	-0.0825	-0.5555	0.0916	-0.0057	-0.0056	-0.0019	-0.0043	-0.0040	0.0382
landlocjt	0.0278	-0.0827	0.0467	-0.0279	0.0546	0.0535	0.0137	0.0410	0.0306	0.1923

	fertit	pestit	ppiit	insqit	trade~jt	ptaijt	adjij	landlo~t
fertit	1.0000							
pestit	0.8838	1.0000						
ppiit	0.9274	0.9273	1.0000					
insqit	-0.6297	-0.5372	-0.6253	1.0000				
tradefreejt	0.3953	0.4451	0.4146	-0.2064	1.0000			
ptaijt	-0.0096	-0.0100	-0.0079	0.0036	-0.2347	1.0000		
adjij	-0.0049	-0.0049	-0.0046	0.0015	-0.0876	0.5569	1.0000	
landlocjt	0.0417	0.0451	0.0377	-0.0093	0.0713	-0.1471	-0.0819	1.0000

Appendix B2. Principles Component Factors

```
Factor analysis/correlation                    Number of obs    =      1,852
    Method: principal-component factors        Retained factors =          5
    Rotation: (unrotated)                      Number of params =         85
```

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	8.41727	6.37863	0.4430	0.4430
Factor2	2.03864	0.51019	0.1073	0.5503
Factor3	1.52844	0.29775	0.0804	0.6308
Factor4	1.23070	0.15045	0.0648	0.6955
Factor5	1.08025	0.10750	0.0569	0.7524
Factor6	0.97275	0.09990	0.0512	0.8036
Factor7	0.87285	0.16573	0.0459	0.8495
Factor8	0.70713	0.02697	0.0372	0.8867
Factor9	0.68016	0.15185	0.0358	0.9225
Factor10	0.52831	0.19565	0.0278	0.9503
Factor11	0.33266	0.03069	0.0175	0.9679
Factor12	0.30197	0.17578	0.0159	0.9837
Factor13	0.12619	0.04730	0.0066	0.9904
Factor14	0.07889	0.02897	0.0042	0.9945
Factor15	0.04992	0.02051	0.0026	0.9972
Factor16	0.02942	0.01839	0.0015	0.9987
Factor17	0.01103	0.00199	0.0006	0.9993
Factor18	0.00904	0.00467	0.0005	0.9998
Factor19	0.00437	.	0.0002	1.0000

LR test: independent vs. saturated: chi2(171) = 4.8e+04 Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Uniqueness
gdpit	0.9097	0.0235	0.0793	-0.0239	0.0130	0.1649
gdpjt	0.1289	-0.1710	-0.0387	-0.0793	-0.6722	0.4945
distij	0.0147	-0.7259	-0.0764	-0.1990	0.2696	0.3547
bexcijt	0.0221	0.0938	-0.1311	-0.2577	0.6014	0.5454
pseit	0.7224	-0.0080	0.6134	-0.0693	0.0544	0.0941
roadit	0.9103	0.0126	0.1806	-0.0094	0.0426	0.1367
roadqit	0.9276	0.0142	0.1609	-0.0083	0.0406	0.1118
railit	0.8075	0.0347	-0.3290	0.0279	-0.0099	0.2376
machit	0.7677	0.0030	0.4750	-0.0717	0.0344	0.1787
aglandit	0.9134	0.0324	-0.2834	0.0328	0.0030	0.0833
aglandjt	-0.0269	0.1316	0.0750	0.7560	-0.0623	0.4009
fertit	0.9262	0.0278	-0.1435	0.0224	0.0253	0.1197
pestit	0.9877	0.0220	0.0257	-0.0005	0.0236	0.0227
ppiit	0.9487	0.0296	-0.1914	0.0261	0.0097	0.0617
insqit	-0.5517	-0.0411	0.7506	-0.1062	0.0084	0.1192
tradefreejt	0.4933	-0.2359	0.0810	-0.0302	-0.2965	0.6056
ptaijt	-0.0308	0.7797	0.0068	-0.1282	0.0673	0.3701
adjij	-0.0165	0.8667	0.0386	-0.0186	-0.0430	0.2448
landlocjt	0.0519	-0.1855	0.1171	0.7101	0.2942	0.3584

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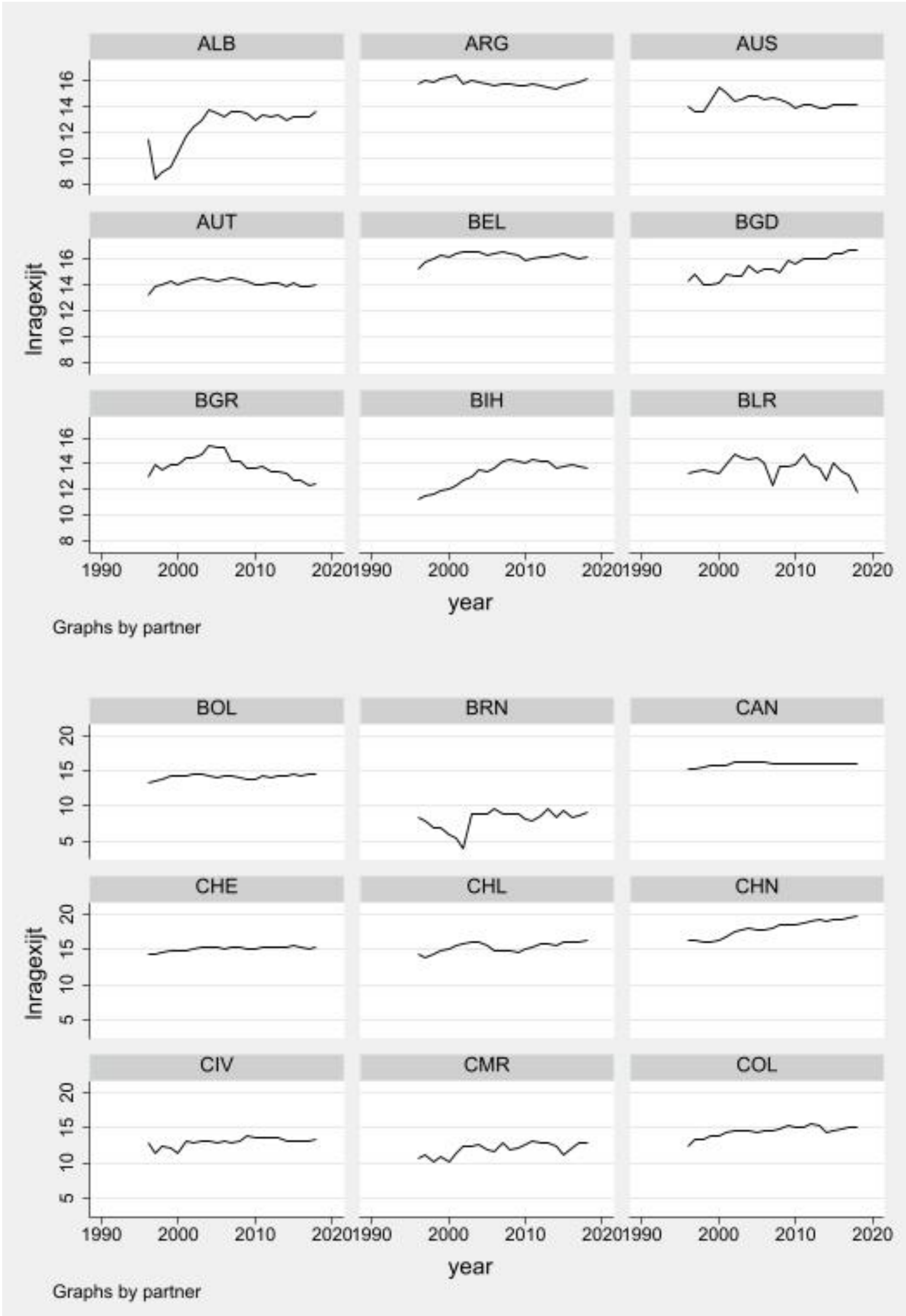
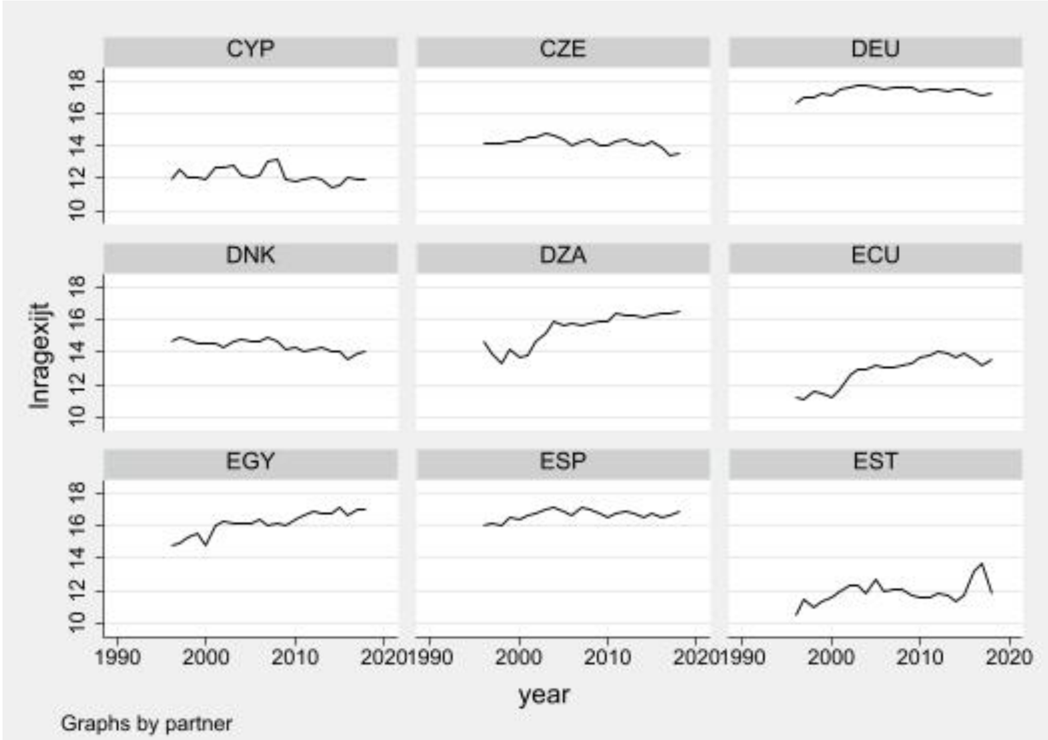
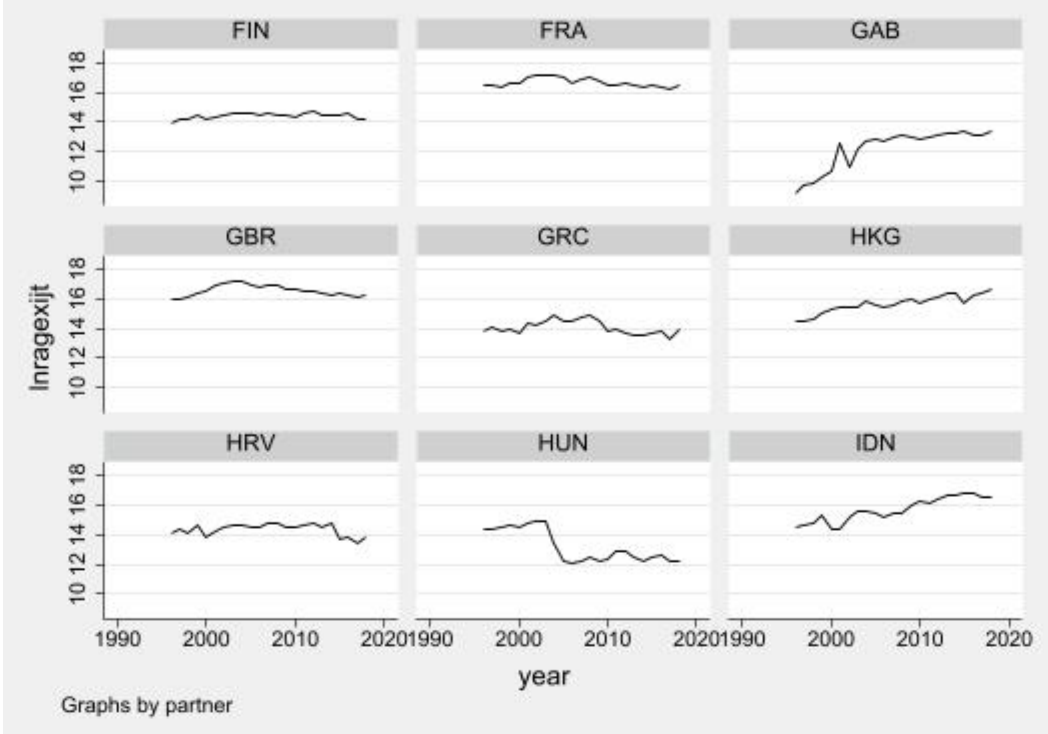
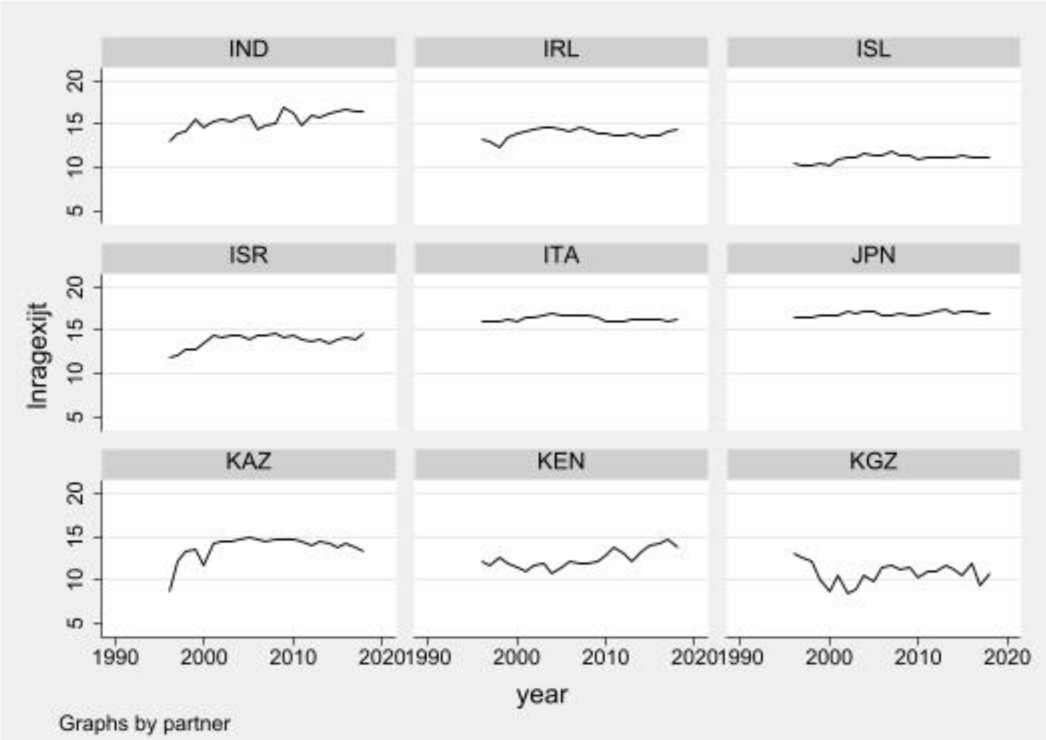
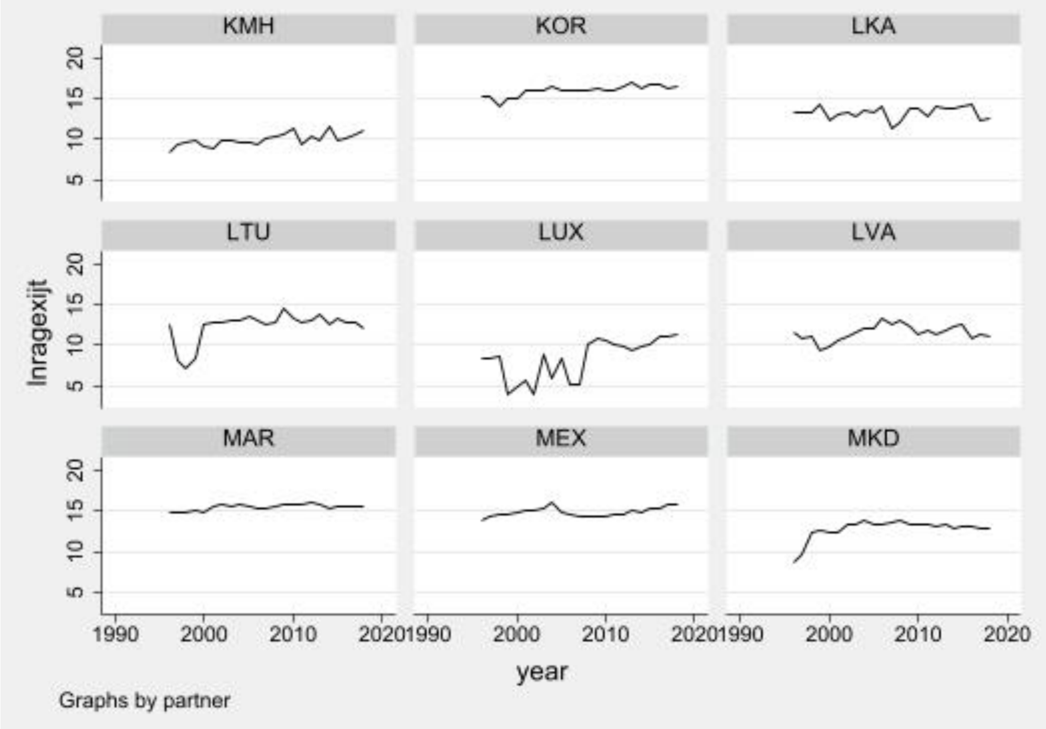
Appendix B3. Sample Countries' Time Trend of Brazilian Agricultural Exports

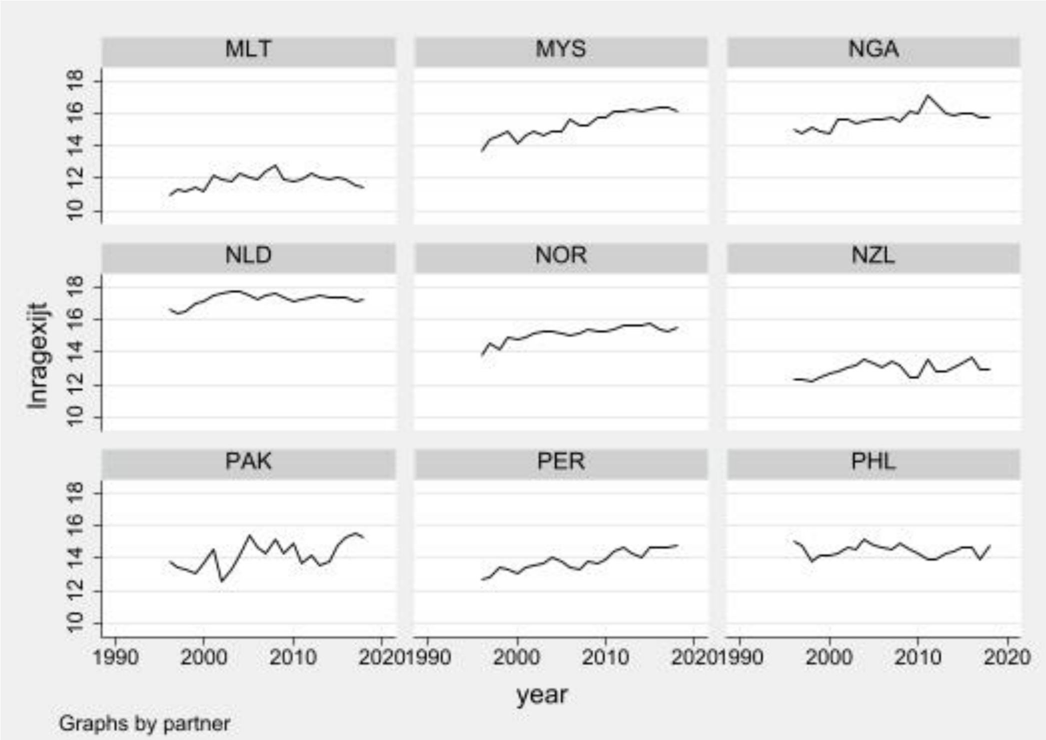



CYP
CZE
DEU
DNK
DZA
ECU
EGY
ESP
EST
lnragexijt
10 12 14 16 18
1990 2000 2010 2020
year
Graphs by partner

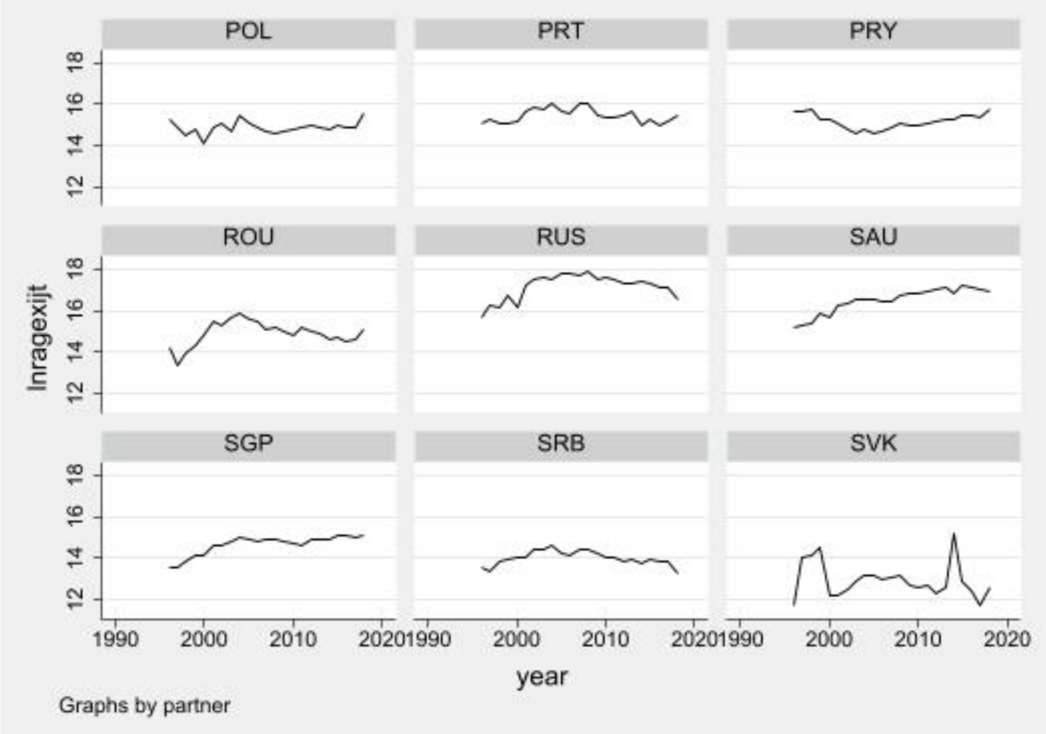

FIN
FRA
GAB
GBR
GRC
HKG
HRV
HUN
IDN
lnragexijt
10 12 14 16 18
1990 2000 2010 2020
year
Graphs by partner


IND
IRL
ISL
ISR
ITA
JPN
KAZ
KEN
KGZ
lnragexijt
5
10
15
20
1990
2000
2010
2020
year
Graphs by partner

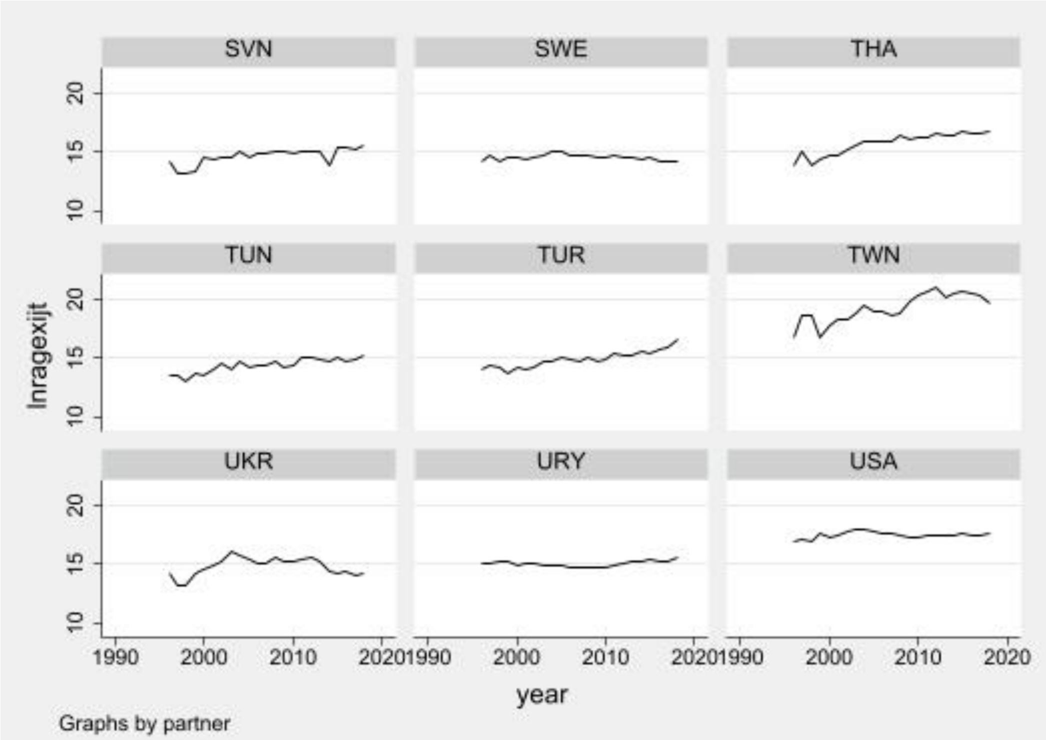

KMH
KOR
LKA
LTU
LUX
LVA
MAR
MEX
MKD
lnragexijt
5
10
15
20
1990
2000
2010
2020
year
Graphs by partner

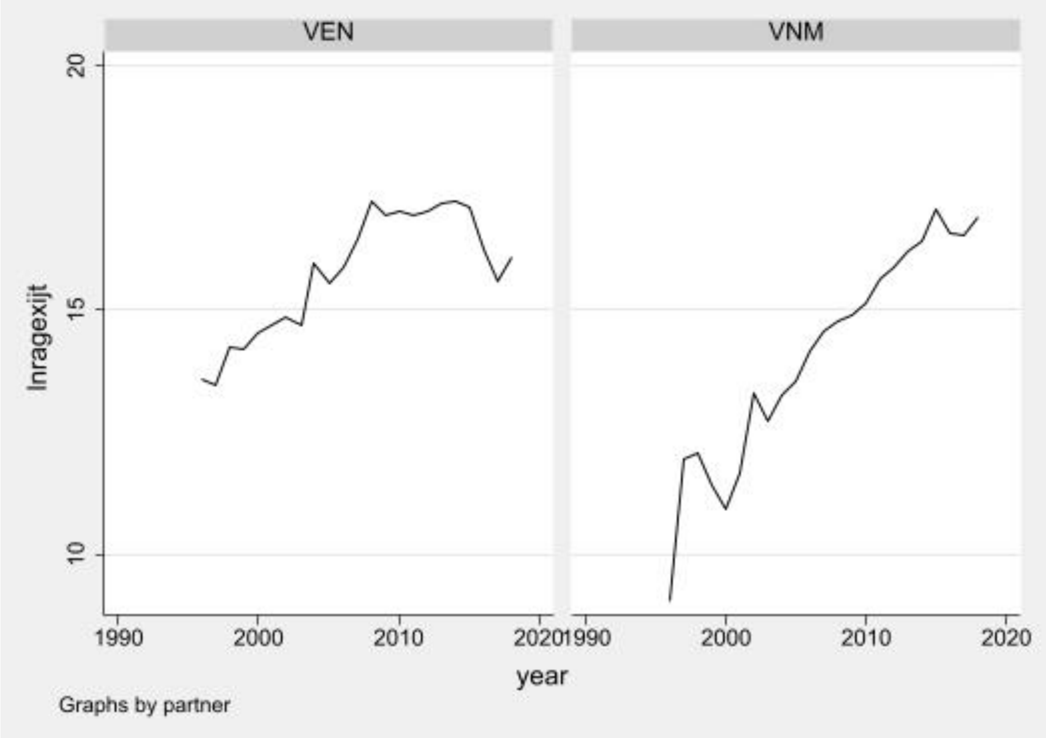


MLT
MYS
NGA
NLD
NOR
NZL
PAK
PER
PHL
lnragexijt
10 12 14 16 18
1990 2000 2010 2020
year
Graphs by partner



POL
PRT
PRY
ROU
RUS
SAU
SGP
SRB
SVK
lnragexijt
12 14 16 18
1990 2000 2010 2020
year
Graphs by partner


SVN
SWE
THA
TUN
TUR
TWN
UKR
URY
USA
lnragexijt
year
Graphs by partner


VEN
VNM
lnragexijt
year
Graphs by partner