

Brazilian soybeans: quo vadis?

Mario Antonio MARGARIDO

Pezco Economics, Brazil

PSP Hub, Brazil

mario.margarido@pezco.com.br

Frederico Araujo TUROLLA

Pezco Economics, Brazil

PSP Hub, Brazil

fredtuolla@pezco.com.br

Abstract. *Historically, Brazil has always stood out in exports of commodities, especially the agricultural ones. Currently, among the commodities exported by the country, stand out the products of the soy complex, (soybean, soymeal and oil). Given the tax structure of the country, there is a predominance in soybean exports. This work initially presents an overview of the international soybean market, involving production, export, import and crushing of this commodity. Also, data on soybean production, area and productivity in Brazil by regions are presented. Next, the issue of logistics for soybean exports is addressed, and the routes for soybean exports were mapped and the Decomposition Method X13-ARIMA-SEATS was applied to remove the seasonality from the series of road freight and heavy vehicle flows on the highways of São Paulo and Paraná. Finally, an Engle-Granger cointegration model was estimated to estimate the long-term elasticities between the value of road freight and international oil and soybean prices.*

Keywords: soybean, seasonality, cointegration, freight, ports.

JEL Classification: C22, R40, R12, Q10.

1. Introduction

Brazil has its economy historically linked to the international price of some *commodity*, since the XVII Century with the gold cycle, which was later replaced by the sugarcane cycle, and then by the coffee cycle. In the most recent period, what can be called the soybean cycle stands out. Soybeans and their derivatives⁽¹⁾, account for roughly 10% of the foreign merchandise sales currently generated by Brazil. The country stands out in the international market in terms of production, exports and productivity in relation to this oilseed. The competitiveness of a country, as in the case of Brazil, based on exports of weight-intensive products, such as soybeans, is directly related to its logistical capacity to transport the production of soybeans. *commodity*. According to Turolla *et al.* (2021, p.3) and Infra2038 Project Estimates⁽²⁾, Brazil has a stock of railway infrastructure assets of 2.3% of GDP⁽³⁾ And it needs to double that stock. Annual investment was at the rate of 0.06% of GDP, while the road sector invests seven times more, or 0.43% of GDP per year. Investment in railways should increase, according to infra2038, by at least 24 billion reais per year."

Still, according to TUROLLA *et al.* (2021), "an important step has already been taken with the development of a model of railway concessions that, accepted by the market, enabled the closure of the country's main longitudinal axis – the North-South Railway – allowing, for the first time in history, a frank growth in the flow of goods through the ports of the Northern Arc. The longitudinal axis is in the process of being complemented by cross-cutting projects such as FICO⁽⁴⁾ -FIOL⁽⁵⁾ and even with a longitudinal alternative along another meridian, the Ferrogrão, all of them in Irish gauge (1.6m). A first section of FIOL has already had its auction successfully carried out." Therefore, it is relevant to know the main factors related to this *commodity*, with an emphasis on the issue of export routes and ports of this *commodity*, as well as its export logistics.

2. Objectives

This study is divided into three parts. The first analyzes the international soybean market, in terms of production, exports, imports, soybean crushing and productivity by country. The second presents and analyzes production, area and productivity data for Brazil, by region. Finally, in the third part, issues related to the logistics of soybean transportation within Brazil are addressed, discussing the issue of seasonality and the transmission of prices for the price of truck freight with the use of the Engle-Granger cointegration model.

3. Overview of the International Soybean Market

According to data from the *Oilseeds* (2021), Brazil is the largest producer and exporter of soybeans. Table 1 shows the production of soybean grains by the main *Players* This

commodity, in addition to the respective percentage shares in the total production of soybeans and the percentage variation between the 2017/18 and 2020/21 crop years. As can be seen in Table 1, the world's three main producers of soybeans practically represent around 80.00% of the soybeans produced in the world, showing the high degree of concentration in the production of soybeans. *commodity*. In percentage terms, it can be observed that, in the period 2017/18 to 2020/21, Argentina's production grew by 24.34%, the production of soybeans in Brazil grew by 11.02%, while there was a 6.26% retraction in the United States production (Figure 1). However, it should be noted that the share of Argentina's production in world production, on average, for the period 201AR7/18 to 2020/21, is equal to 13.40%, while Brazil's average share, in the same period, is equal to 36.00%. Therefore, although the variation in production in Argentina is higher than the percentage change presented by Brazil (24.34% against 11.02%), the variation in production in Argentina starts from a much lower base compared to the base that prevails in the case of Brazil.

Table 1. *Soybean Production by Country and World Total, World Percentage Share and Percentage Change Rate for the period 2017/18 to 2020/21 (in thousands of metric tons)*

Production/Country	2017/18	2018/19	2019/20	2020/21
Brazil	123400	119700	128500	137000
United States	120065	120515	96667	112549
Argentina	37800	55300	48800	47000
World Total	344181	361277	339418	364066
Percentage*	81.72	81.80	80.72	81.45

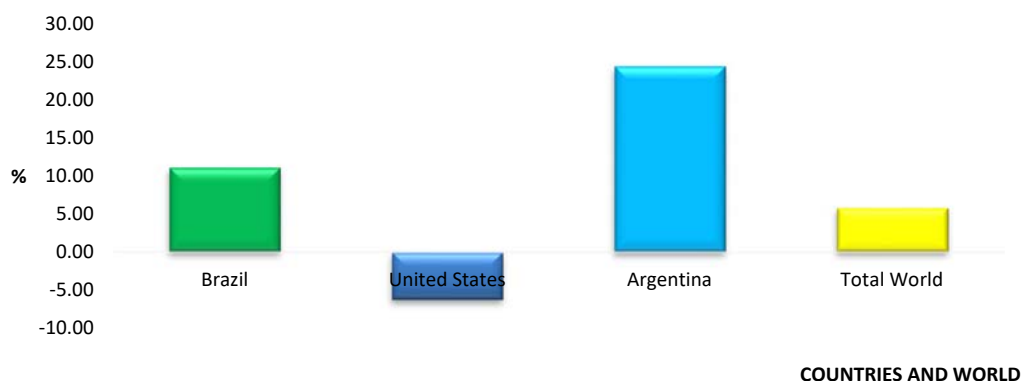
*Percentage of the combined production of Brazil, the United States and Argentina, in relation to the world production of soybeans.

Source: Prepared by the authors based on *Oilseeds* (2021).

In relation to world exports of soybeans, only two countries dominate this market, Brazil and the United States, which, on average, participate with 85.00% of world exports of soybeans. *commodity*, with an average participation of 51.48% in Brazil, and the United States with an average participation of 33.45% for the 2017/18-2020/21 period (Table 2). In terms of percentage change, exports of soybeans from Brazil changed by 12.96% in the period between 2017/18-2020/21, while exports from the United States grew by 6.85% (Figure 2 2). In other words, Brazil's share of world soybean exports was almost twice as high as the percentage change of its main competitor, the United States.

In the case of imports, only two stand out *Players*also. China and the European Union, on average, account for 68.48% of world imports of this oilseed. For the period from 2017/18 to 2020/21, imports of soybeans from the European Union in relation to imports from China grew by 7.44% against 6.28%, however, imports from China, in the same period, were, on average, 6.44 times higher than imports from the European bloc, which remained practically stable in the same period (Table 3).

Figure 1. Percentage Change in Soybean Production, Brazil, United States, Argentina and World, 2017/18-2020/21



Source: Prepared by the authors based on *Oilseeds* (2021).

Table 2. Soybean Exports by Country and World Total, World Percentage Share and Percentage Change Rate for the period 2017/18 to 2020/21 (in thousands of metric tons)

Export/Country	2017/18	2018/19	2019/20	2020/21
Brazil	76136	74887	92135	86000
United States	58071	47676	45777	62051
World Total	153240	148893	165135	171409
Percentage*	87.58	82.32	83.51	86.37

*Percentage of exports added by Brazil and the United States, in relation to world soybean exports.

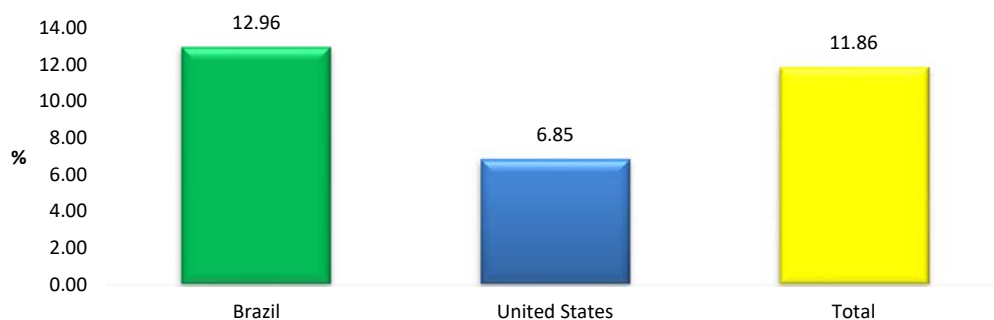
Source: Prepared by the authors based on *Oilseeds* (2021).

Figure 3 shows the percentage changes for China and the European Union based on the period 2017/18-2020/21. Although the European Union presents a higher variation than China, it should not be forgotten that China's imports, in the same period, were almost 6.5 times, as mentioned in the previous paragraph, that is, the European Union's basis of comparison is much lower than China's.

The soybean is the main input to obtain the noblest product of the soybean complex, the meal, which is widely used for the production of animal feed, with a view to the production of animal protein (chickens, pigs and cattle confined) and for the food industry, as well. World crushing data show that the country that crushes the most soybeans is China, which crushes almost twice as much as the United States (Table 4). On average, for the period from 2017/18 to 2020/21, China, the United States, Brazil and Argentina crushed almost 76% of the world's soybeans. Another fact to be highlighted is that, although soybean production in Brazil, on average from 2017/18 to 2020/21, is almost 2.7 times higher than Argentina's production, in relation to crushing, the quantities crushed by Brazil and Argentina are very close. This result reflects the respective policies of each country. While Argentina chooses to give preference to soybean exports, Brazil prefers soybean exports. Argentina's policy encourages the export of bran, through the payment of bonuses to exporters, and, at the same time, taxes the export of the grain. In the case of Brazil, the

Kandir Law stimulates the export of soybeans, as exports are not taxed, while the commercialization of soybeans in the domestic market is taxed via ICMS, discouraging its crushing within Brazil. This stimulates the export of grain to the detriment of bran, generating jobs in the importing country.

Figure 2. *Percentage Change in Soybean Production, Brazil, United States and World, 2017/18-2020/21*



Source: Prepared by the authors based on *Oilseeds* (2021).

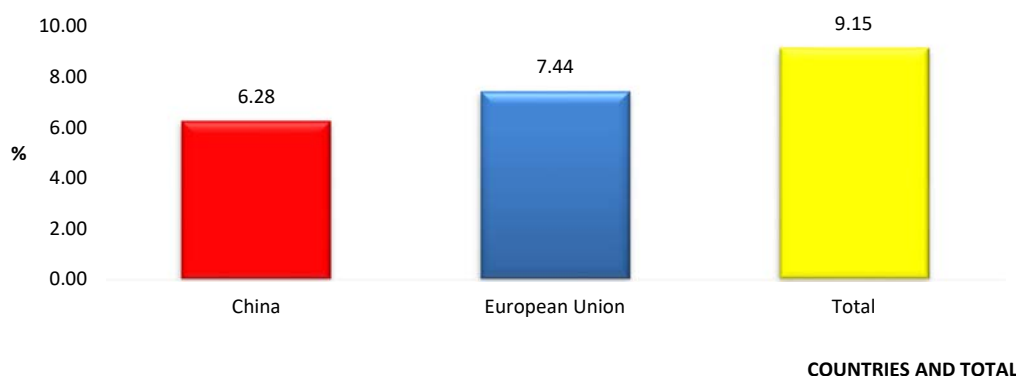
Table 3. *Soybean Imports by Country and World Total, World Percentage Share and Percentage Change Rate for the period 2017/18 to 2020/21 (in thousands of metric tons)*

Import/Country	2017/18	2018/19	2019/20	2020/21
China	94095	82540	98533	100000
European Union	13915	14346	14947	14950
World Total	153741	145881	165019	167809
Percentage*	70.25	66.41	68.77	68.50

*Percentage of imports combined by China and the European Union, in relation to world soybean imports.

Source: Prepared by the authors based on *Oilseeds* (2021).

Figure 3. *Percentage Change in Soybean Imports, China, European Union and World, 2017/18-2020/21*



Source: Prepared by the authors based on *Oilseeds* (2021).

Table 4. Soybean Crushing by Country and World Total, World Percentage Share and Percentage Change Rate for the period 2017/18 to 2020/21 (in thousands of metric tons)

Crush/Country	2017/18	2018/19	2019/20	2020/21
China	90000	85000	91500	96000
United States	55926	56935	58910	59194
Brazil	44205	42527	46000	46750
Argentina	36933	40567	38770	41500
World Total	294992	298671	311496	322059
Percentage*	76.97	75.34	75.50	75.59

*Percentage of crushing combined by China, the United States, Brazil and Argentina, in relation to world soybean crushing.

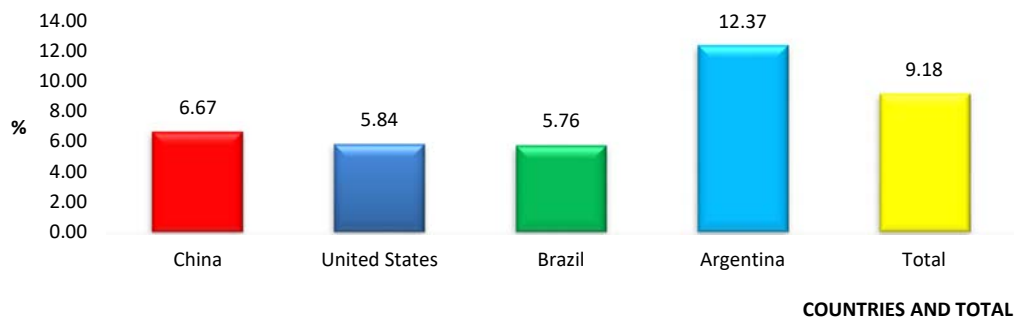
Source: Prepared by the authors based on *Oilseeds* (2021).

Also, as for crushing, in terms of percentage changes, covering the period 2017/18-2020/21, the *ranking* it is led by Argentina, while China occupies the second position, with almost half of Argentina's crushing (variation of 12.35% against 6.67%), as can be seen in Figure 4. Among the three largest soybean producers, Brazil occupies the third position, with a change of 5.76% (Figure 4).

In terms of the evolution of the area harvested with soybeans, it is observed that, while the area harvested in the United States shows a downward trend, the area in Argentina remained practically stable, in the case of Brazil, there is an upward trend in the area harvested in the period 2017/18-2020/21 (Table 5).

The data involving percentage change for the same period show that there was a retraction of 8.07% in the area harvested with soybeans in the United States, while the areas harvested in Brazil and Argentina grew 9.82% and 1.23%, respectively, for the same period (Figure 5). The justification for the reduction in the area harvested with soybeans in the United States is mainly due to the fact that the United States began to encourage the production of corn-based ethanol in the last decade, thus aiming to reduce its dependence on oil from the Middle East. Given that the United States no longer has agricultural frontier areas, the only alternative is crop substitution, that is, in order to plant more corn, it is necessary to reduce the area with soybean production. In the case of Brazil, the increase in area is mainly due to the incorporation of native forests into the production process, since the country has an agricultural frontier, and also, however, on a smaller scale, in the substitution of other crops for soybeans, due to changes in the relative prices of agricultural products.

Figure 4. Soybean Crushing Percentage Change, China, United States, Brazil, Argentina and World, 2017/18-2020/21



Source: Prepared by the authors based on *Oilseeds* (2021).

Table 5. Soybean Harvested Area by Country and Percentage Change Rate for the period 2017/18 to 2020/21 (in thousands of hectares)

Planted Area by Country	2017/18	2018/19	2019/20	2020/21
United States	36236	35448	30327	33313
Brazil	35150	35900	36900	38600
Argentina	16300	16600	16700	16500

Source: Prepared by the authors based on *Oilseeds* (2021).

Figure 5. Percentage Change of Harvested Area with Soybeans, United States, Brazil and Argentina, 2017/18-2020/21



Source: Prepared by the authors based on *Oilseeds* (2021).

Based on the information in Tables 1 and 5, it is possible to determine the productivity for Brazil, Argentina and the United States. It is observed that in most of the period between the 2017/18 and 2020/21 crop years, Brazil was the country with the highest productivity per area, with the exception of the 2018/19 crop year. (Table 6).

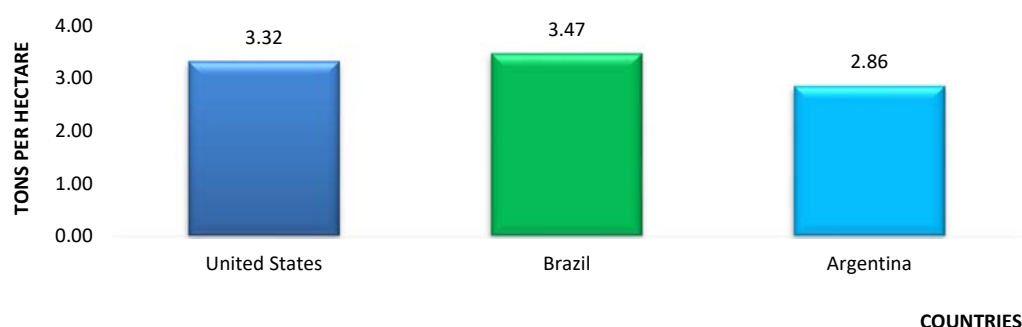
In terms of average productivity for the period 2017/18 to 2020/21, it is observed that, in descending order, the country with the highest productivity is Brazil with 3.47 tons per hectare, followed by the United States with 3.32 tons per hectare and, finally, Argentina with 2.86 tons per hectare (Figure 6). Given that a bag of soybeans weighs 60 kilograms, just divide the amount produced into tons per hectare, and divide by 60 kilograms. In this case, the soybean yield in Brazil is equal to 57.82 bags per hectare, while for the United States it is equal to 55.33 bags per hectare, and in the case of Argentina, its productivity is 47.59 bags per hectare.

Table 6. Soybean Harvested Area by Country and Percentage Change Rate for the period 2017/18 to 2020/21 (in tons per hectare)

Productivity by Country	2017/18	2018/19	2019/20	2020/21
United States	3.31	3.40	3.19	3.38
Brazil	3.51	3.33	3.48	3.55
Argentina	2.32	3.33	2.92	2.85

Source: Prepared by the authors based on *Oilseed* (2021).

Figure 6. Average Productivity per Soybean Harvested Area, United States, Brazil and Argentina, 2017/18-2020/21



Source: Prepared by the authors based on *Oilseeds* (2021).

4. Soybean Market in Brazil: overview

Specifically, in relation to Brazil, according to data from the National Supply Company (CONAB, 2021), for the period from 2017/18 to 2020/21, on average, the Midwest region produced 58,119 thousand tons, making it the main soybean producing region in Brazil. In second place is the South region, with a production of 39,494 tons (Table 7).

Also, taking into account the average soybean production, for the period 2017/18 to 2020/21, the Midwest region concentrated 46.16% of the Brazilian soybean production, and the second region that produces the most soybeans is the South region, with 31.36% (Figure 7). Therefore, these two regions alone account for 77.5% of Brazilian soybean production (Figure 7).

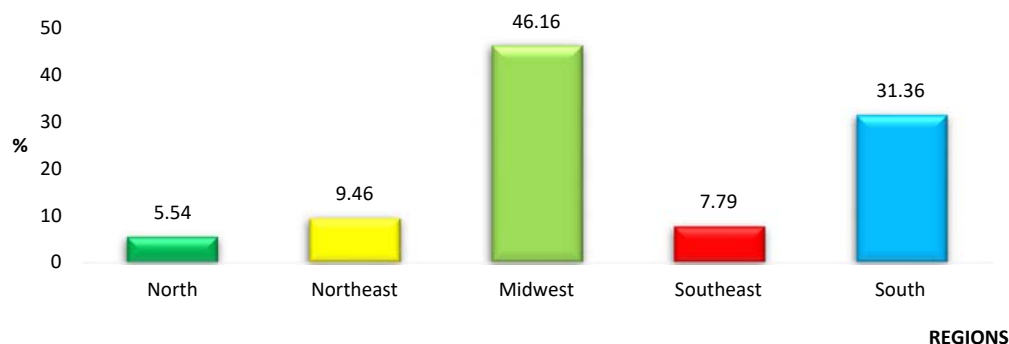
The highlight in the Midwest region is the State of Mato Grosso, which alone represents, on average for the period 2017/18 to 2020/21, about 27.4% of the national soybean production.

Table 7. Soybean Grain Production, Average Production and Average Share, Brazil and Regions, for the period 2017/18 to 2020/21
(in thousands of tonnes)

Region/Country	2017/18	2018/19	2019/20	2020/21 Forecast (¹)	AVERAGE
NORTH	6012	6147	6902	7321	6596
NORTHEAST	11903	11035	11820	12870	11907
MIDWEST	55398	55058	60698	61322	58119
SOUTHEAST	9157	8614	10131	11318	9805
SOUTH	40788	38864	35295	43032	39494
BRAZIL	123259	119718	124845	135861	125921

(¹) Estimate in June 2021.

Source: Prepared by the authors based on basic data from CONAB (2021).

Figure 7. Average Soybean Production by Region, Brazil, Period 2017/18 – 2020/2021

Source: Prepared by the authors based on basic data from CONAB (2021).

The area planted with soybeans in Brazil, on average, for the period 2017/18 to 2020/21, is also concentrated in the Midwest and South Regions, with 16402 and 12044 thousand hectares, respectively (Table 8). Individually, the highlight is the State of Mato Grosso, which holds 27% of the area planted with soybeans in the country.

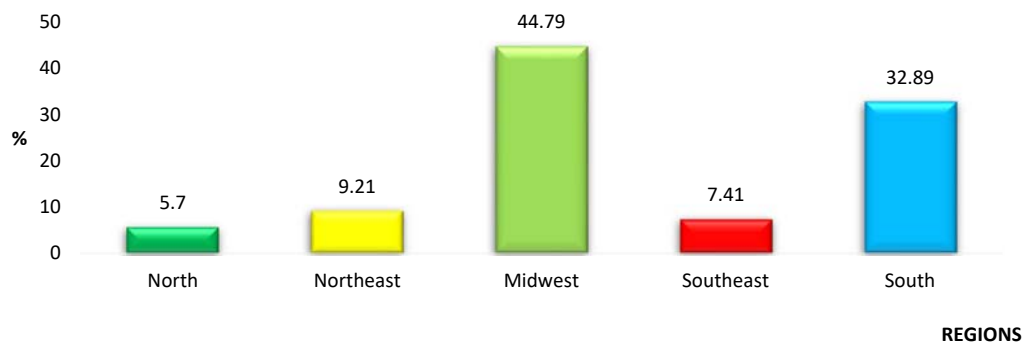
Table 8. Soybean Planted Area and Average Planted Area, Brazil and Regions, for the period 2017/18 to 2020/21 (in thousands of hectares)

Region/Country	2017/18	2018/19	2019/20	2020/21 Forecast (¹)	AVERAGE
NORTH	1932	1988	2111	2312	2086
NORTHEAST	3264	3332	3357	3544	3374
MIDWEST	15649	16103	16640	17216	16402
SOUTHEAST	2470	2571	2757	3061	2715
SOUTH	11835	11880	12085	12375	12044
BRAZIL	35149	35874	36950	38509	36620

(¹) Estimate in June 2021.

Source: Prepared by the authors based on basic data from CONAB (2021).

In terms of participation, the average planted area for the period 2017/18 – 2020/21, the Midwest and South regions stand out, with average participation each with 44.78% and 32.89%, respectively (Figure 8).

Figure 8. Average Soybean Planted Area by Region, Brazil, Period 2017/18 – 2020/2021

Source: Prepared by the authors based on basic data from CONAB (2021).

Table 9 shows soybean yield by region and Brazil for the period from 2017/18 to 2020/21. The data indicate that the region that has the highest productivity by area is the Southeast region. Although the highlights in the soybean market are the Midwest and South regions, which have the highest production and planted area, the Southeast region is the one with the highest productivity, especially the state of São Paulo. This is basically justified by the following factor. The state of São Paulo does not have an agricultural frontier, unlike what happens in relation to the Midwest region, so to increase soybean production, there are two ways, one would be to reduce the area of some other product to leverage the area with soybean production, an effect resulting from changes in relative prices. In the case of São Paulo, soybeans would have competition from sugarcane and pastures. Alternatively, intensify the use of modern technologies, such as fertilizers, pesticides, genetically improved machinery and tractors, seeds, etc., in order to leverage productivity while maintaining the area planted with soybeans, that is, without providing significant changes in the area planted with soybeans.

Table 9. *Soybean Productivity, Brazil and Regions, for the period 2017/18 to 2020/21 (In Kg/hectare)*

Region/Country	2017/18	2018/19	2019/20	2020/21 Forecast (¹)
NORTH	3.11	3.09	3.27	3.17
NORTHEAST	3.65	3.31	3.52	3.63
MIDWEST	3.54	3.42	3.65	3.56
SOUTHEAST	3.71	3.35	3.68	3.70
SOUTH	3.45	3.27	2.92	3.48
Brazil	3.51	3.34	3.38	3.53

(¹) Estimate in June 2021.

Source: Basic data from CONAB (2021).

The average soybean yield for the period 2017/18 to 2020/21 shows that the Southeast region is the one with the highest productivity per area with 3.61 Kg/ha, followed by the Midwest region with an average yield of 3.54 Kg/ha. In third place, however, very close to the Midwest region, is the Northeast region with 3.53 kg/ha (Figure 9).

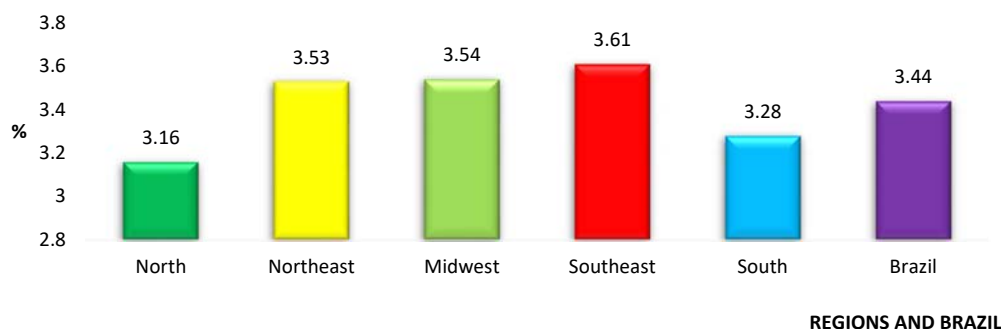
5. Logistics Issues for Soybean Exports in Brazil

Despite having continental dimensions and being the main *player* in the world soybean market, Brazil transports a significant portion of its soybean crop by road, which is more expensive than transport by waterway and rail, contrary to what happens in Argentina, where rail predominates, and in the United States, with a predominance of waterway. In this case, the country's competitiveness in the international soybean market is basically linked to its high productivity, which, so far, more than compensates for the costs of our deficient infrastructure. Also, another favorable factor is the country's geographical position, which allows maritime transport from Brazil to China, the main market for soybeans, to have lower transportation costs compared to soybeans produced in the United States and shipped to China.

The soybean-producing areas in Brazil are relatively far from their respective ports for soybean exports. *commodity*, a fact that increases the costs of transporting them to the port of destination in Brazil.

According to *Soybean Transportation Guide – Brazil* (2021), ports in the South and Southeast regions are responsible for 62% of all soybeans exported by Brazil, while ports in the Northeast region account for 26%, and ports in the North region account for 12% (Figure 10).

Figure 9. Average Soybean Yield by Region, Brazil, Period 2017/18 – 2020/2021.



Source: Prepared by the authors based on basic data from CONAB (2021).

In general, in relation to the flow of soybeans in the North region, it is observed that part of the soybean production in the north of Mato Grosso goes by truck along BR364 to Porto Velho in Rondônia (on average 1,000 km), where the soybeans are loaded on barges, and, via the Madeira and Amazon rivers, arrive at the port of Santarém in Pará to be loaded onto bulk carriers for export. Also, in relation to the flow of soybeans from the north of Mato Grosso, the road modal is used along the BR163 highway to the port of Itaituba/Miritituba, where the soybeans are transferred to barges and taken to the port of Santarém for export (Figure 10).

Alternatively, another way for soybeans to be exported through the North region is to transport soybeans produced in Mato Grosso, Goiás, and Tocantins, along the BR158 and BR153 highways, to the river port of Marabá, where the soybeans are transferred to barges and transported to the port of Barcarena for export (Figure 10).

The soybeans produced in the south of Maranhão and south of Piauí have the port of destination for export, the port of São Luís, and the transportation of this soybean to São Luís occurs by road (Figure 10).

Soybeans produced in western Bahia have two alternatives. Take the BR242 highway to Salvador, or also by road, but the BR415 highway to the port of Ilhéus (Figure 10).

In relation to the southern region, soybeans produced in the west of Rio Grande do Sul are transported by truck, using the BR392 highway to the port of Rio Grande (Figure 10).

Part of the soybeans produced in Mato Grosso, Mato Grosso do Sul, Paraná, is transported by road to the port of Paranaguá (Figure 10).

Finally, part of the soybeans produced in the Midwest and Southeast regions (Mato Grosso, Mato Grosso do Sul, Goiás and Minas Gerais) is transported by truck, and another portion

is transported by rail, from the Rondonópolis railway terminal in Mato Grosso to the port of Santos in São Paulo (Figure 10).

The numbers on the map below represent the main cities of origin of the soybeans to be transported, their respective route and their respective mode of transport (Figure 11). As can be seen, the road modal predominates, despite the long distances between soybean production and its final destination for export.

Basically, the production of soybeans for export in the Midwest region, the most important producing region in the country, has the following options. Part of this production is transported via highway-railroad to the Southeast region (Santos), by trucks and barges to the ports of the North region, and mainly by trucks to the port of the South region (Paranaguá). Another important soybean producing and exporting region is the northwest of Rio Grande do Sul, where the road modal predominates and the port of destination is in Rio Grande (Figure 11). Also noteworthy is the flow of the soybean harvest to the port of Paranaguá, mainly using the road modal, and this port receives trucks from the states of Paraná, Goiás, Mato Grosso do Sul, and even Mato Grosso (Figure 11).

Figure 10. Soybean Export Routes, Modes of Transport and Ports, Brazil, 2019



¹ World Wildlife Fund.

² Brazilian Institute of Geography and Statistics (IBGE)—Municipal Agricultural Production.

Source: USDA/Agricultural Marketing Service (AMS) and USDA/Foreign Agricultural Service (FAS), 2021.

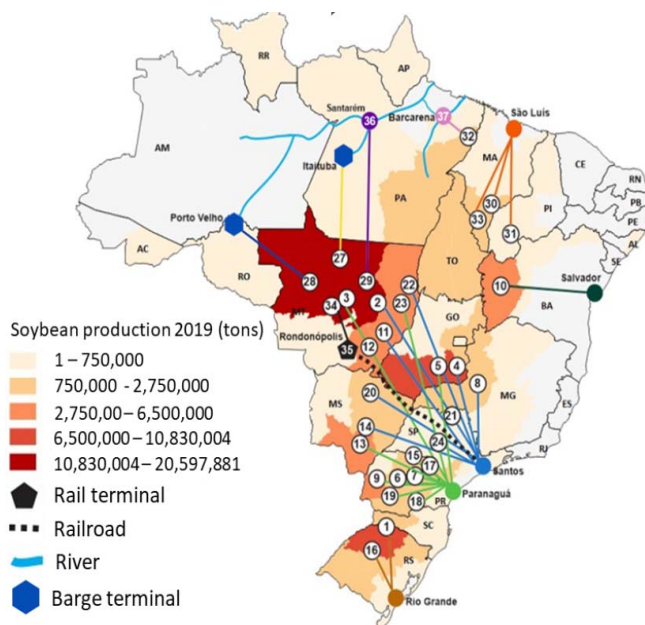
Given the increase in soybean production in the Midwest region over the last few years, and due to the bottlenecks for the flow of the increasing volume of the soybean crop coming from this region for export through the ports of the Southeast (Santos) and South (Paranaguá), this has resulted in an increase in the costs of transporting the grain crop. Due

to these difficulties, feasibility studies were initiated for the export of the grain crop, with emphasis on soybeans, through the ports of the North region. The ports of the North and Northeast regions. they are situated above the 16th Parallel, and are called ports that form the Northern Arc.

Basically, two factors are relevant to the competitiveness for the flow of the soybean crop through the ports of the Northern Arc. Due to the characteristics of the North region, its rivers have excellent navigability, allowing the transportation of grains by barges, whose costs are lower than those of the road modal. Another geographical factor refers to altitude, while in order to make the soybeans reach the ports of the South and Southeast, it is necessary to overcome high altitudes (Serra do Mar), in the case of the North region, they are plains (small variations in altitude), and this factor contributes significantly to the reduction of the cost of transporting grains.

Figure 12 shows the distances to be traveled in miles by trucks⁽⁶⁾ loading soybeans from the North, Southwest and Northeast regions of Mato Grosso, with Sorriso, Primavera do Leste and Canarana, respectively, as reference cities to the ports of Santos (Southeast) and Paranaguá (South) and the distances traveled by trucks originating in the same three reference cities. however, towards the ports of Arco Norte⁽⁷⁾, Itaituba (Pará), Porto Velho (Rondônia) and Santarém (Pará). Based on the information in Figure 12, on average, by road, to the port of Santos, it is 1013.67 miles (1631.33 km), to the port of Paranaguá, on average, it is 1104 miles (1776.71 km). On the other hand, taking into account the three ports of the Arco Norte, having as reference the same cities of Mato Grosso, the average distance to be traveled by road to these ports is equal to 726.66 miles (1169.45 km).

Figure 11. *Origin, destination and mode used to transport the soybean crop in Brazil*



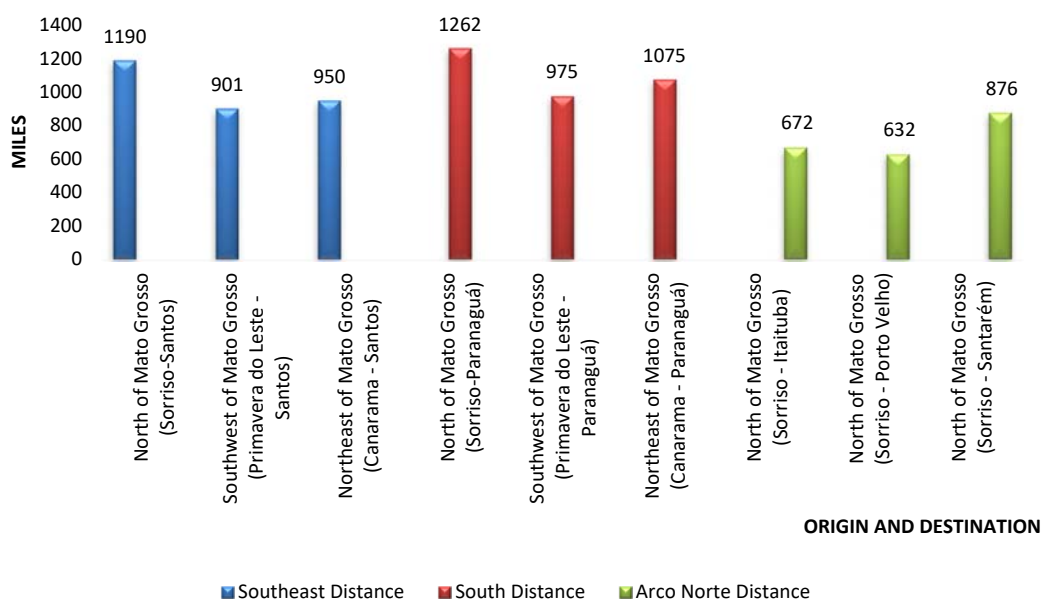
Source: USDA/Agricultural Marketing Service (AMS) and USDA/Foreign Agricultural Service (FAS), 2021.

According to Notícias Agrícolas (2021), a "barge (unit that makes up the vessel) can transport up to 1,500 tons in cargo. Compared to road transport, each barge is equivalent to 60 trailers, which can carry a maximum of up to 25 tons." Also, according to Notícias Agrícolas (2021), comparing river transport in relation to rail transport, the former is also more economically efficient, since a barge replaces fifteen wagons with a capacity to load one hundred tons. Therefore, it is more advantageous for the northern region of Mato Grosso to use the combination of road and river modal for the export of soybeans through the ports of the Northern Arc, than to use exclusively the road modal to the ports of the South and Southeast regions.

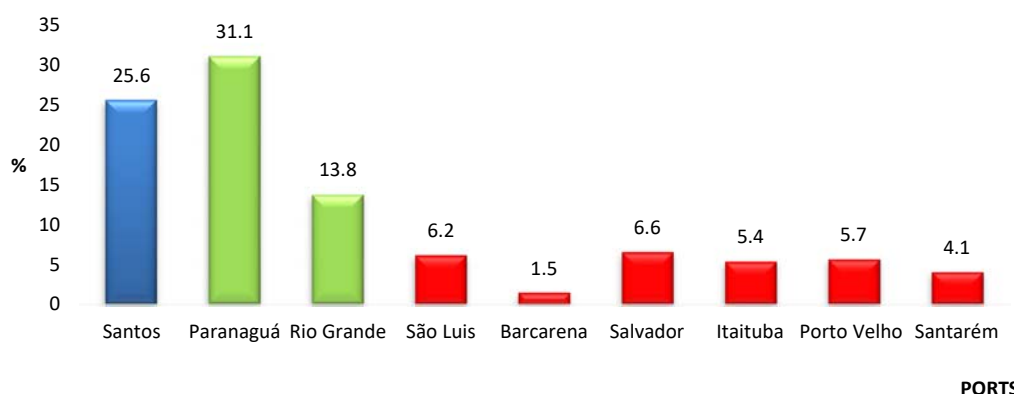
In the total soybeans exported by Brazil, 31.9% originate in Mato Grosso, and soybeans from the north of Mato Grosso correspond to 8.7% of what is exported through the port of Santos, while Paranaguá participates with 8.0%, and the ports of Arco Norte contribute with 15.2% of the total soybeans exported by the country.

Figure 13 shows the percentage of soybeans exported at each port in Brazil in 2019. In that year, of the total soybeans exported by the country, 25.6% of the soybeans were exported through the port of Santos, while the port of Paranaguá participated with 31.1%, Rio Grande with 13.8%, São Luís 6.2%, Barcarena 1.5%, Salvador 6.6%, Itaituba 5.4%, Porto Velho 5.7%⁽⁸⁾ and Santarém with 4.1%, respectively. Therefore, of the total soybeans exported by the country, 25.6% originate in the Southeast region, while the South region participates with 44.9% and the ports of the Northern Arc with 29.5%.

Figure 12. Distance between the soybean-producing reference regions in the north of Mato Grosso to the ports of the South, Southeast and Arco Norte regions, in miles, 2019



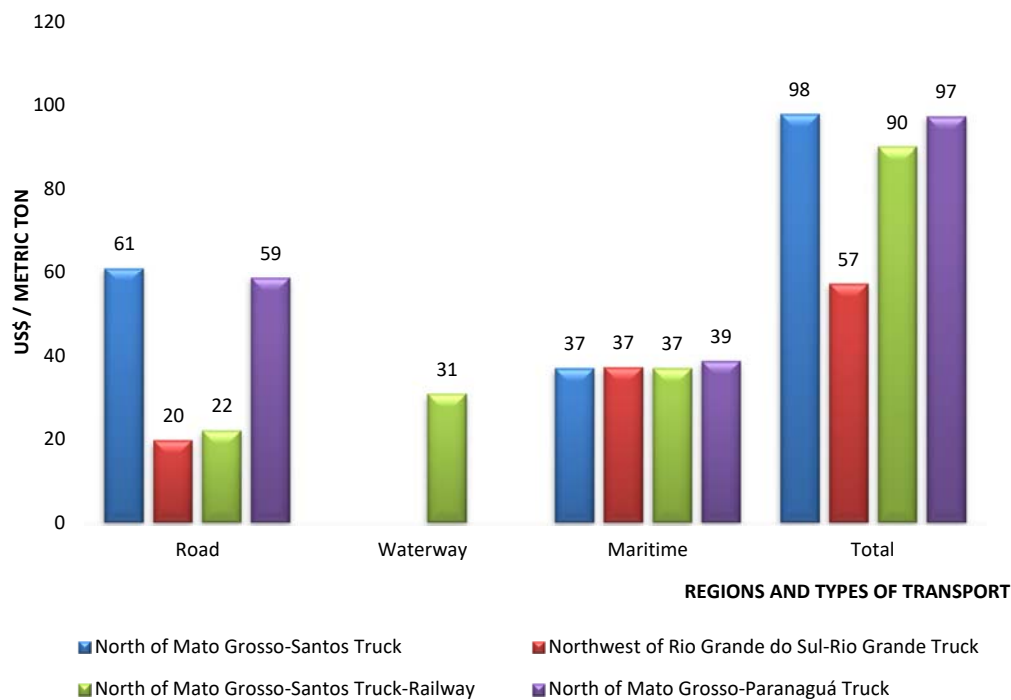
Source: Prepared by the authors USDA/Agricultural Marketing Service (AMS) and USDA/Foreign Agricultural Service (FAS), 2021.

Figure 13. *Percentage Share of Soybean Exports by Port, Brazil, 2019*

Source: Prepared by the authors from USDA/Agricultural Marketing Service (AMS) and USDA/Foreign Agricultural Service (FAS) data, 2021.

Figure 14 shows the transportation costs of soybeans according to the main soybean shipment base regions, as well as the respective modes of transport used to the port of destination for export, based on the values for the first quarter of 2021. Based on the road modal, the highest transportation cost falls on soybeans whose origin is the north of Mato Grosso and has as its final destination the port of Santos, with freight equal to 61 US\$ / metric t. The lowest transportation cost occurs in the path of soybeans originating in the northwest of Rio Grande do Sul and final destination in the port of Rio Grande, with freight equal to 20 US\$ / metric ton (Figure 14). This difference is due to the distance traveled, because from the north of Mato Grosso to Santos, it is 1,190 miles, while from the northwest of Rio Grande do Sul to Rio Grande, it is only 288 miles. The only stretch that involves road/rail modes, originates from soybeans coming from the north of Mato Grosso and goes to the port of Santos, which has a cost equal to 53 US\$ / t. metric, that is, the combination of road/rail transport represents only 86% of the cost of the exclusive use of the road modal from the north of Mato Grosso to the port of Santos. In relation to sea freight, there are no significant differentials (Figure 14). Finally, in relation to the total cost of transporting soybeans, which takes into account all the modes involved, to the respective port of destination, the most expensive is the transportation of soybeans from the north of Mato Grosso to the port of Santos, using exclusively the road modal, which has a cost equal to 98 US\$ / t. metric. Based on the same region of origin to the port of Santos, however, using the combination of road/rail modes, the total cost is equal to 90 US\$ / t. metric, i.e., 91.83% of the cost in relation to the exclusively road mode. Remembering that, by road only, it is 1,190 miles from the north of Mato Grosso to the port of Santos, while, by the combination of road/rail modes, it is 382 miles, with soybeans originating in Sorriso to Rondonópolis where the railway terminal is located and another 1,091 miles to the port of Santos, with the total distance being equivalent to 1,473 miles.

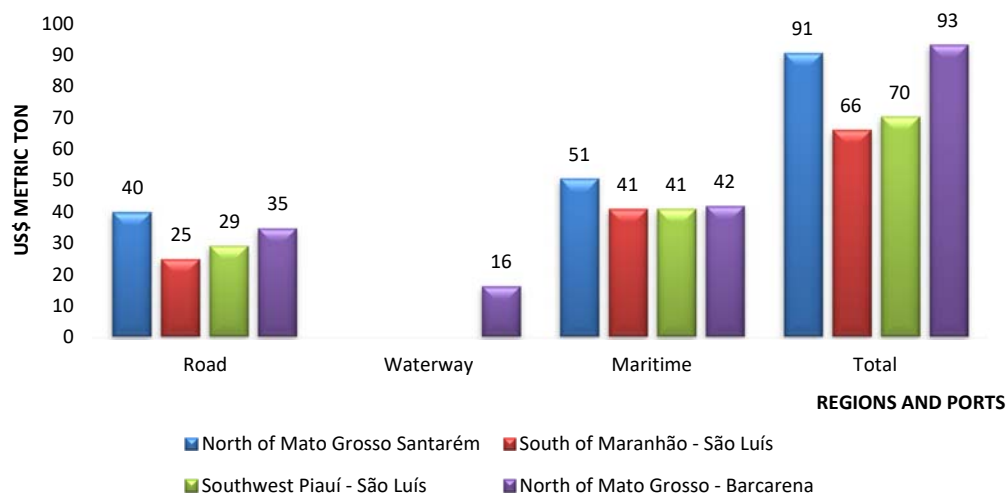
Figure 14. *Origin of Soybean Production, Type of Modal to Port of Destination, South and Southeast Regions, Brazil, First Quarter of 2021*



Source: Prepared by the authors from USDA/Agricultural Marketing Service (AMS) and USDA/Foreign Agricultural Service (FAS) data, 2021.

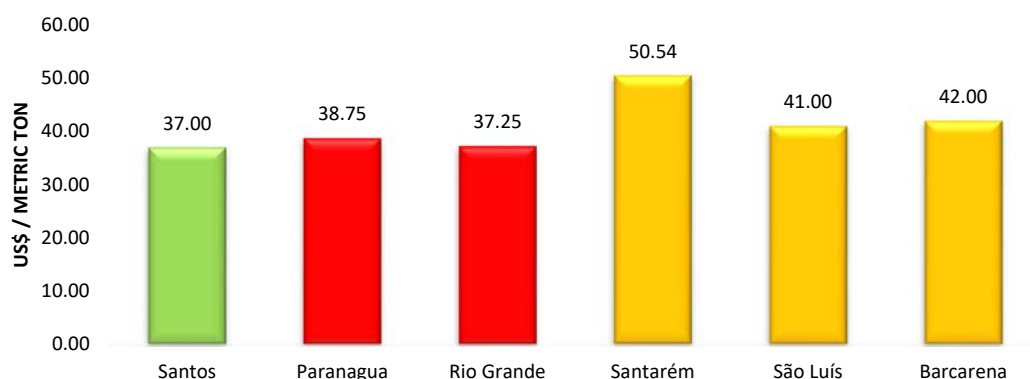
Regarding the ports of the Northern Arc, a part of the soybeans originating in the north of Mato Grosso uses only the road modal to the port of Santarém, in this case, the road freight is equal to 40 US\$ / metric ton in the first quarter of 2021, being the most expensive (Figure 15). Another portion of the soybeans produced in the north of Mato Grosso is destined for the port of Barcarena, and in this case, the combination of road/waterway modes is used, with the soybeans going by truck to Marabá, where they are transshipped to barges, then transported to the port of Barcarena for export, in this case, the cost of transportation by road alone is equal to US\$ 35/t. metric. However, when also taking into account the freight through the waterway, which is equal to US\$16/t. metric, the cost rises to 51 US\$/t. metric. However, sea freight is the most expensive of all the other export options through the ports of the Northern Arc. In total, it is still more advantageous to use only the road modal, whose cost is equivalent to 91 US\$ / t. metric against 93 US\$ / t. metric of the road/waterway modals (Figure 15). This result probably shows that there is inefficiency in infrastructure in the region, because the waterway, which is a cheaper transport than the road, is not yet competitive. Although soybeans originating in the south of Maranhão and southwest of Piauí are transported exclusively by road, these two regions are the most competitive, however, this is due to the proximity of the respective regions in relation to the port of São Luís, with these distances equal to 482 miles and 606 miles, respectively.

Figure 15. *Origin of Soybean Production, Type of Modal to Port of Destination, North and Northeast Regions, Brazil, First Quarter of 2021*



Source: Prepared by the authors from USDA/Agricultural Marketing Service (AMS) and USDA/Foreign Agricultural Service (FAS) data, 2021.

Given that the main importer of Brazilian soybeans is China, remembering that imports from China represent eight times the exports of soybeans to the European Union, the second largest market for Brazilian soybeans, it becomes relevant to analyze the issue of sea freight. Figure 16 shows the value of sea freight for the first quarter of 2021, based on the respective port of export. Given their respective geographical positions, the cost of freight to China (Shanghai) is lower for the ports of the Southeast and South regions, and the highlight is the port of Santos, with sea freight equal to 37 US\$ / metric ton (Figure 16). All ports in the Southeast and South regions have freight rates below 40 US\$ / metric ton, while the ports of the Northern Arc have higher freights and all above 40 US\$ / t. metric (Figure 16). On average, the sea freight to the ports of the South and Southeast regions is equal to 36.66 US\$/t. metric, while on average, too, the sea freight to the ports of the Northern Arc is equal to 41.54 US\$/t. metric. Therefore, it is more expensive, on average, to export soybeans through the ports of the Northern Arc compared to the ports of the South and Southeast regions, that is, in terms of percentage change, the cost is 13.31% more expensive, on average, to export through the ports of the Northern Arc compared to the ports of the South and Southeast regions. Possibly, these results can be reversed, in geographical terms, when considering soybean exports to the European Union, where, probably, the costs of sea freight in the ports of the Northern Arc should be lower than those practiced in the ports of the South/Southeast regions, however, this is beyond the scope of this text, as it aims to analyze the soybeans that effectively go to Asia.

Figure 16. Sea freight from the Port of Origin to Shanghai, Values in US\$ / t. metric, Brazil, First Half of 2021

Source: Prepared by the authors from USDA/Agricultural Marketing Service (AMS) and USDA/Foreign Agricultural Service (FAS) data, 2021.

6. Data

The next step is to analyze the behavior of road freight values and the flows of heavy vehicles on the highways of the states of São Paulo and Paraná. The justification is that a significant portion of the soybeans exported by road, which originates in the Midwest region, uses the roads of São Paulo and Paraná, towards the ports of Santos and Paranaguá, which are the largest ports of exit of Brazilian soybeans towards the international market. The data on road freight refers to the freight of soybeans transported by truck, whose unit is US\$ / t. metric / 100 miles, whose sources are University of São Paulo, Escola Superior de Agricultura "Luiz de Queiroz," Brazil (ESALQ/USP) and USDA, Agricultural Marketing Service (2021). The series is monthly, and starts in January 2003 and runs until March 2021. The series of heavy vehicle flow indexes, based on 1999=100, on the highways of the states of São Paulo and Paraná, are based on the Brazilian Association of Highway Concessionaires (ABCR).

However, before starting the analysis of the respective series, it is necessary to know the period of harvest, commercialization and transportation of soybeans in Brazil. As presented in Machado and Margarido (2004), based on data from the Brazilian Association of Vegetable Oil Industries (ABIOVE), the soybean harvest in Brazil begins between February and March, depending on weather conditions, and its commercialization and transportation extends until September/October (Figure 17).

Figure 17. Harvest and Marketing Periods, Soybean, Brazil, Argentina and United States

	J	F	M	A	M	J	J	A	S	O	N	D
EUA												
BRAZIL												
ARGENTINE												

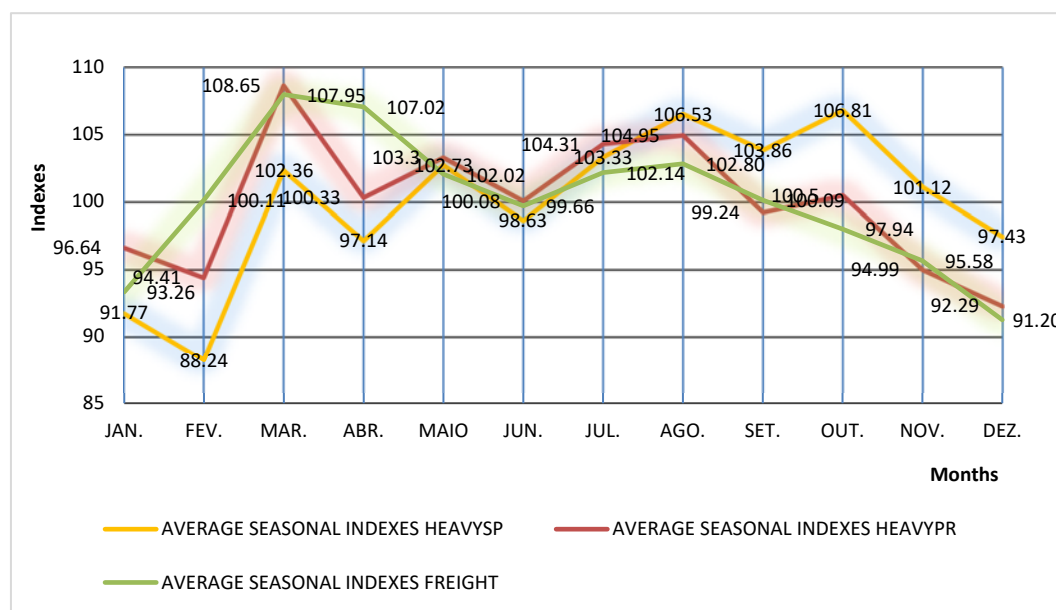
Source: Prepared by Machado and Margarido (2004) based on information from ABIOVE.

7. Methods and Analysis of Results

The Decomposition method was used *X-13 ARIMA SEATS*⁽⁹⁾, as presented by the *U.S. Census Bureau* (2017), to deseasonalize the series of truck freight, and flows of heavy vehicles on the highways of São Paulo and Paraná. Figure 18 shows the average monthly seasonal indices for the three seasonally adjusted variables, which are called *AVERAGE SEASONAL INDICES FREIGHT*, *HEAVY AVERAGE SEASONAL INDICES SP* and *HEAVY AVERAGE SEASONAL INDICES PR* respectively.

In the case of the seasonal average indices for the flow of heavy vehicles on São Paulo highways, the peak of the indices occurs in October with a value equal to 106,81, while the minimum value occurs in February with a value of 88,24. For the flow of heavy vehicles on Paraná's highways, the peak occurs in March with a value equal to 108,65, while your voucher, or minimum value, occurs in December with a value of 92,29. Finally, as for the average seasonal indices for the freight value variable, its maximum value is March with a value equal to 107,95 and minimum value in December with a value equal to 91,20 (Figure 18).

Figure 18. Monthly Average Seasonal Indexes, Indices of Heavy Vehicle Flows on the Roads of São Paulo and Paraná and Truck Freight in Brazil, January 2003 – June 2021



Source: Prepared by the authors based on basic data from ABCR and USDA.

Correlation coefficients were calculated⁽¹⁰⁾ between the flow of heavy vehicles on the roads of Paraná and the freight of trucks and between the flow of heavy vehicles on the roads of São Paulo and the freight of trucks. The results show a correlation coefficient equal to 79.56% in the first case and 28.32% in the second case.

Regarding Paraná, it is necessary to highlight that the state is one of the main producers of soybeans in Brazil, so the high correlation with truck freight is natural. In addition, it does

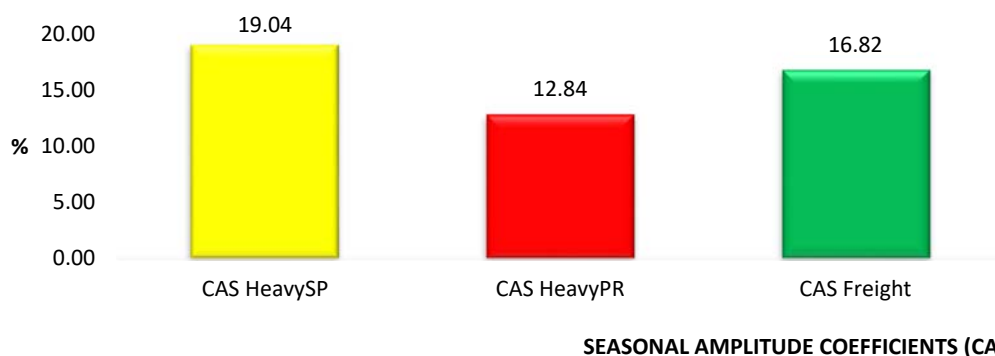
not have rail transport, and also passes through a significant portion of soybeans originating in the Midwest region, up to the port of Paranaguá. Thus, this result is robust. Also, the fact that the highest average seasonal index is located in March is a function of the beginning of the soybean harvest in the country, as shown in Figure 17.

On the other hand, in relation to the results for the state of São Paulo, it is necessary to highlight that the state is not a major soybean producer, however, it is a transit point for a relevant part of the soybean production from the Midwest region to the port of Santos. Also, it is necessary to highlight that another relevant part of soybean production in the Midwest crosses the state of São Paulo, but by rail, a factor that reduces the use of road transport in this state. Another possible explanation for the lower correlation found between road freight for grains and the flow of heavy vehicles on the roads of São Paulo, and also for the differences found between the months of the highest and lowest seasonal indices in relation to the flow of heavy vehicles in Paraná, refers to the fact that the economic structure of the state of São Paulo is based on industry and not on agricultural production. Thus, possibly, the fact that the highest seasonal index for the flow of heavy vehicles on São Paulo roads is in October, is related to the fact that industrial production has its highest volume in the second half of the year, and the peak of São Paulo's industrial production is allocated between the months of August/September. Thus, the greater flow of heavy vehicles on the roads of São Paulo is due to the transportation of products produced by the industry to the retail chains in October, so that the latter can make these products available to consumers between the months of November and December, and December is the best month of sales in the retail sector. On the other hand, the lower flow of heavy vehicles refers to the month of February, a period that has fewer working days (28 or 29 days), in addition to generally having the Carnival holiday, which is a long holiday, and the number of working days is a relevant factor for industrial production. and, consequently, for the transport of road cargo.

Figure 19 shows the respective Seasonal Amplitude Coefficients for each of the three variables. The goal, in this case, is to determine the magnitude of seasonality. As can be seen in Figure 19, the variable with the most seasonality is the flow of heavy vehicles on the roads of São Paulo, with a coefficient value equal to 19.04%. Next, there is the CAS of the variable truck freight with a value of around 16.82%, and, finally, the flow of heavy vehicles on the roads of Paraná with a magnitude equal to 12.84%.

The result of the flow of heavy vehicles on the roads of Paraná presenting lower CAS in relation to the CAS for the flow of heavy vehicles on the roads of São Paulo, is possibly justified by the fact that the flow of soybean production occurs over seven/eight months, as shown in Figure 17, attenuating the seasonal factor, while the transportation of industrial production in São Paulo is more concentrated in the second half of the year. staying between two or three months, a fact that accentuates the seasonal amplitude.

Figure 19. Seasonal Amplitude Coefficients, Indices of Heavy Vehicle Flows on the Roads of São Paulo and Paraná and Truck Freight in Brazil, January 2003 – June 2021.



Source: Prepared by the authors based on basic data from ABCR and USDA.

Since the presence of seasonality was detected in the three series, the *X13-ARIMA SEATS* Decomposition method was used to remove seasonality. Thus, each seasonally adjusted series, freight, oil price and soybean price, are denominated as *FREIGHT-d11*, *PET_d11* and *SOYBEAN_d11*, respectively. Since it is desired to obtain the respective price transmission elasticities, the Neperian logarithm was applied to each of the three series, which are called *l_FRETE-d11*, *l_PET_d11* and *l_SOYBEAN_d11*, respectively.

After removing the seasonality of each series, the Augmented Dickey-Fuller Unit Root (ADF) test was applied to determine the order of integration of each variable. The results show that all variables are integrated of order one (*I(1)*). Next, a regression model was estimated with the level series, and the residuals of this regression were "captured". After this procedure, the ADF test was applied to the residuals of this regression. The previous procedure is called the Engle-Granger cointegration test. The results showed that the waste is stationary. This result shows that the regression is not spurious and that the variables cointegrate, that is, converge towards equilibrium in the long run⁽¹¹⁾.

The results of the Engle-Granger cointegration regression are shown in Table 10. The constant and the estimated coefficients for the variables *l_PET_d11* and *l_SOYBEAN_d11*, are statistically significant at a significance level of 1% (Table).

Table 10. Results of the Cointegration Equation, variables *l_FRETE-d11*, *l_PET_d11* and *l_SOYBEAN_d11*, January 2003 – March 2021

	Coefficient	Std. error	T-ratio	P-value
Const	-2.02589	0.216356	-9.364	1.05E-017 ***
<i>l_PET_d11</i>	0.609848	0.039101	15.6	3.09E-037 ***
<i>l_SOYBEAN_d11</i>	0.1817	0.049816	3.647	0.0003 ***

Significant at a significance level of 1%.

Source: Prepared by the authors from basic data from the IMF and USDA.

The error correction term has a value equal to -0.20046, which means that imbalances in the road freight variable are corrected by 20.04% each period. Therefore, the long term is equivalent to approximately five months. Based on these results, a variation of 1% in the international price of oil induces a variation of 0.6088% in the price of road freight, in up

to five months, configuring an inelastic relationship. On the other hand, a variation of 1% in the international price of soybeans results in a variation of 0.1817% in the price of road freight in up to five months, a relationship that is also inelastic. Therefore, the main variable to explain the value of road freight is the fuel effect, represented here by the international price of oil, however, the product effect, represented by the international price of soybeans, also contributes to explain the value of freight, but to a lesser extent.

Final thoughts

The fact that road freight is linked to the price of fuel, which in turn is linked to the international price of oil, is a relevant and restrictive factor for the use of road transport as the main means of transport for a country with continental dimensions, and can serve as a basis for the development of projects involving other more economically efficient modes. such as, for example, rail modes, and, above all, waterways, with emphasis on the Arco Norte region. It is necessary to bear in mind that, given the specificities of rail and waterway modes, it is necessary to complement the road modal to feed the first two modes. As previously presented, the Arco Norte represents a relevant alternative for the flow of agricultural production, especially from the Midwest region, however, there is still a need for investments to improve its infrastructure. As an example, a possible way to reduce transport costs and reduce the environmental impact due to the intensive use of road transport in the Arco Norte, is the construction of the Ferrogrão⁽¹²⁾ with an extension of 933 km, connecting Sinop in the north of Mato Grosso to Miritituba in Pará, in addition to other investments in infrastructure in the North and Northeast regions. in order to reduce dependence on road transport, which. It is ideal for short distances, but not for long distances. According to TUROLLA (2021, p.3), all "this configures a new geography of the Brazilian railway system. Increasingly, heavy logistics targeting the Northern Hemisphere will use more rational maritime exits in the northern direction of Brazil, rather than "going down before you go up", or focusing their attention on the saturated ports of the Southeast and South regions." The previous statement is confirmed by the most recent data from Brazil Soybean Transportation (2023), while in 2013, the country exported 3.5 million metric tons through the ports of the Northern Arc, that is, 12% of total soybean exports, in the same period, exports through the traditional ports of the Southeast and South regions, exports totaled 37.5 million metric tons, which corresponds to 88% of the total exported. In 2022, this relationship undergoes a significant change, as in that year, soybean exports through the Northern Arc totaled 25.7 million metric tons, that is, 33% of the total soybean exported by the country, while the Southeast and South regions exported 52.4 million metric tons, that is, 66% of the total exported that year. As a result of these future investments, the expectation is to further increase Brazil's competitiveness in the international soybean market.

Notes

- (1) The so-called soybean complex encompasses grain, bran and oil.
- (2) <https://www.infra2038.org/>
- (3) Gross Domestic Product.
- (4) Midwest Integration Railway.
- (5) West-East Integration Railway.
- (6) One mile equals 1.60934 km.
- (7) It is necessary to highlight that the ports of the Northern Arc involve the ports of the North and Northeast regions, they are: São Luís (MA), Barcarena (PA), Salvador (BA), Itaituba (PA), Porto Velho (RO) and Santarém (PA). However, only the flow of soybean production from the north of Mato Grosso, whose relevant ports are the last three mentioned, is being analyzed.
- (8) Remembering that the soybeans shipped in Porto Velho are transported on barges along the Madeira River to the ports of Itaquatiara and Santarém, where they are transferred to the ships.
- (9) Details about the X13-ARIMA SEATS Method and its application can be found in MARGARIDO (2021).
- (10) Details on the Correlation Coefficient can be found in MARGARIDO (2020b).
- (11) It should be noted that all the procedures described will not be presented depending on the space issue. For those who wish to know the theory and application for each of the methods mentioned above, the suggestion is to consult MARGARIDO (2020a).
- (12) Details on the railway issue in Brazil can be found in TUROLLA *et al.* (2021).

References

- Associação Brasileira das Concessionárias de Rodovias (ABCR) <<https://abcr.org.br/>>
- Associação Brasileira das Indústrias de Óleos Vegetais (ABIOVE) <<https://abiove.org.br/>>
- Brazil Soybean Transportation. U.S. Department of Agriculture: Agricultural Marketing Service. 2022 Overview, February, 2023.
- CONAB. Companhia Nacional de Abastecimento (CONAB). 2021. Available at: <<http://www.conab.gov.br/info-agro/safras/serie-historica-das-safras/itemlist/category/911-soja>>
- Infra2038. Annual report. Available at: <<https://www.infra2038.org/>>
- Machado, E.L. and Margarido, M.A., 2004. Evidence of Seasonal Price Transmission in Soybean International Market. *Revista de Economia Aplicada*, São Paulo, Vol. 8, No.1, pp. 127-141.
- Margarido, M.A., 2021. *Modelos de Séries Temporais: teoria e aplicações utilizando o software GRET*. São Paulo: Pezco Editora e Desenvolvimento, 358 p.
- Margarido, M.A., 2020a. *Teoria e Aplicações de Modelos de Séries Temporais em Economia*. São Paulo. 481 p.
- Margarido, M.A., 2020b. *Econometria Essencial*. São Paulo. 260 p.
- Notícias Agrícolas. <<https://www.noticiasagricolas.com.br/noticias/agronegocio/38482-brasil-desperdica-potencial-hidroviario--20-vezes-mais-barato-que-o-transporte-por-rodovias.html#.YPm4WOHkg2w>> [Acesso 22 de julho de 2021].

- Oilseeds: Word Market and Trade*. United States Department of Agriculture (USDA), Jun. 2021. <<https://downloads.usda.library.cornell.edu/usda-esmis/files/tx31qh68h/wm118k79f/2227nm257/oilseeds.pdf>>
2021. *Soybean Transportation Guide – Brazil*. U.S. Department of Agriculture: Agricultural Marketing Service.
- Tuolla et al., 2021. *A Nova Geografia Ferroviária Brasileira e o Papel da Regulação do Acesso ao Eixo Longitudinal*. São Paulo: Pezco Economic & Financial Analysis e LL Advogados. Maio. 2021. 15 p.
2021. USDA/Agricultural Marketing Service-AMS-USDA/Foreign Agricultural Service-FAS.
2017. X13 ARIMA SEATS. Reference Manual. Time Series Research. Staff Center for Statistical Research and Methodology. U.S. Census Bureau. Washington, DC.