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Soybean Supply Chains, Markets, and Global Trade

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Abstract Soybean is one of the most important commodities worldwide. It is an essential source of vegetal protein, and it has been used for human nutrition, animal feeding, and biofuel production. The main growers and exporters are Brazil, the United States, and Argentina accounting for almost 82% of total soybean exports by quantity in any form in 2021 (FAO, 2023). On the other hand, this is a highly concentrated supply chain where China receives to more than 56% of imports by quantity in 2021. On-shore logistics is a bottleneck for many countries, but the off-shore is efficient and produces a great quantity of movement

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between a few producers and the market in a low-cost transportation process. Finally, environmental concerns over the impact of soybean overproduction motivate environmental protection legislation. In this chapter, we investigate the evolution of this global supply chain over the years and present an outlook of the market considering uses, world trade, logistics, and environmental impacts. To do so, we conducted a literature review on the topic, collected statistical data from international organizations, and illustrated the current state of soybean supply chain using descriptive statistics and social network analysis. Our results will inform policymakers in regulating the soybean market.

Keywords: Soybean, Supply Chain, Secondary Data Analysis, Benchmarking, Network Analysis

1. Introduction

Soybean is one of the most important world commodities. Basically, it is a grain produced mainly in the American continent, where countries such as Argentina, Brazil, and the United States are the most representative ones. The reason why this scenario occurred is linked to the last century when soybeans began to be grown in the continent to produce oil for the Second World War efforts (Chang et al. 2015). Nowadays, these three countries account for almost 90% of the world production (Mendes dos Reis et al. 2020).

Soybean is used as a grain or as oil. Soybean grain is rich in oil, and around 85% of world production is crushed (Murphy et al. 2012). Crushed soybean is transformed into soybean meal or soybean cake. A soybean meal is a flour rich in protein that is the residue of the crushed soybean and can be used as a way to feed livestock such as swine, chicken, and cows. Usually, the soybean meal is mixed with corn before it is fed to animals.

Despite the huge production in the American continent, the main markets are located in Asia, where China is the most important market, buying more than 50% of the world's

production (Ali et al. 2022). Due to this long journey from America to Europe or Asia, maritime logistics has been developing in the last decades, and each day, more bulk ships are transporting grains worldwide. The cost of soybean grain transportation is around 50% of the cost of transporting it as oil, which makes buyers prefer to buy the grain because, besides the transportation prices, they can obtain three different products locally (Reis et al. 2016).

When we think about this complex market involving production, distribution, and consumption, it is not difficult to realize the existence of a high concentration of trading companies appropriating supply chain rentability. Five companies can be cited in this segment: ADM (A), Bunge (B), Cargill (C), Dreyfuss (D), and, nowadays the Chinese Cofco. The ABCD trade represents more than 70% of the world's soybean trade (Mendes dos Reis et al. 2020; Murphy et al. 2012).

In this chapter, we seek to understand the soybean market by studying its origins, main uses, trade marketing, logistics process, and environmental impacts.

2. Main Uses of Soybeans

The soybean is a grain that can be consumed in different ways. It can be consumed as natural grain, or we can be crushed to produce oil. This oil produces biofuel or can be refined to produce food products such as vegetable butter. According to Murphy et al. (2012), about 95% is consumed as edible oil, and 5% is used for industrial products such as fatty acids, soaps, and biodiesel.

Around 85% of the world’s production is crushed (Murphy et al. 2012). From the crushing process, we obtain the soybean meal or soybean cake, which can be used in feeding animal processes, mainly the productive ones such as swine, cows, and chicken, because it is rich in protein. Approximately 98% of this soybean meal is processed from animal feed, and 2% is used to make soy flour and proteins (Murphy et al. 2012).

A soybean grain can contain 36% protein, 15% soluble carbohydrates, 15% insoluble carbohydrates, and 18% oil. The production process starts with the harvest of soybean grains. The seeds are separated, dried, and shipped to a processing plant where protein is produced on different lines. Soybeans pass through serrated rollers to break each bean into several pieces, and the outer hulls are removed by aspiration and blended into animal feed. Beans are crushed using smooth rollers, forming flakes, while the oil is extracted using hexane (Thrane et al. 2017). The schematics of soybean processing can be seen in Figure 1.

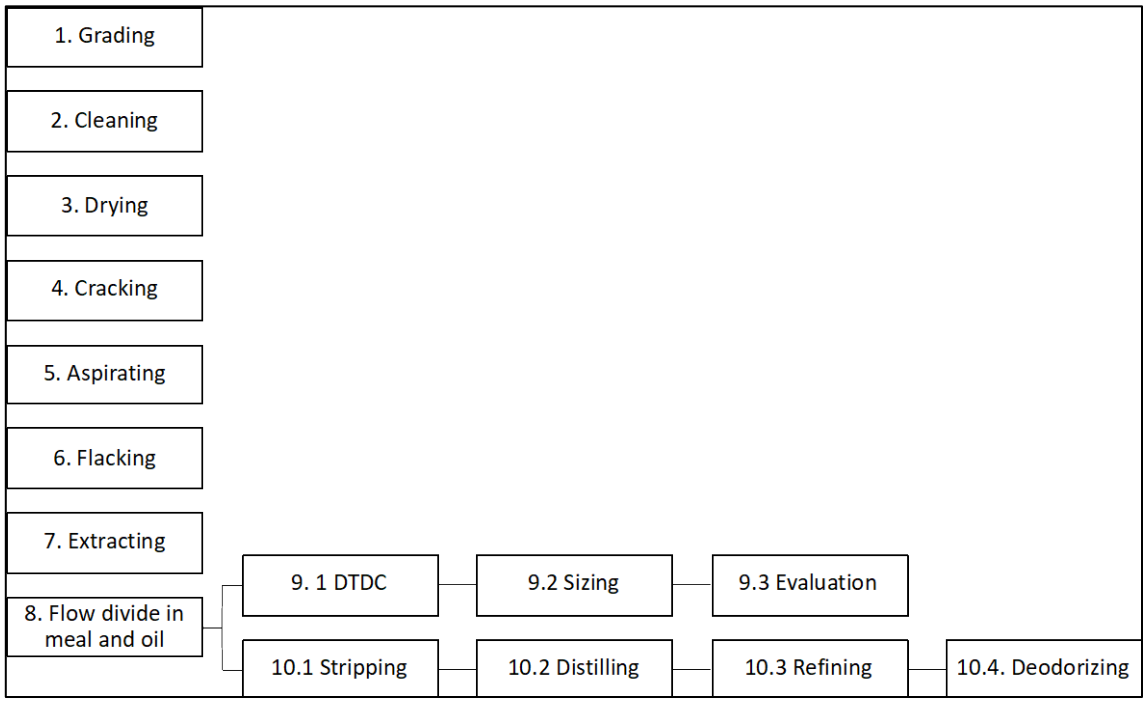

Figure 1. Soybean Crush Processing. Adapted from (United Soybean Board, 2019)

The stages of crush processing can be described as follows (United Soybean Board, 2019):

- Grading: Soybeans are graded considering weight, moisture, protein, and oil content.
- Cleaning: Soybeans pass through screeners to remove foreign materials, hulls, and weed seeds.
- Drying: Soybeans can be subjected to either of the two processes: traditional drying, where grains are dried down to 11% moisture pop the hull, and hot dehulling, where grains are flash dried using heat, which pops hulls quicker.

- Cracking: Rollers crack soybeans into six and eight pieces.
- Aspirating: Hulls are separated from kernels using airflow.
- Flaking: Kernels are flattened in flakes using rollers to disrupt the oil cell structure.
- Extracting: Hexane solvent runs over flakes, extracting the oil.
- Flow divides in meal and oil: In this step, the grain is crushed and follows next steps 9 and 10.
- Meal
    - DTDC: Flakes are put into Desolventizing, Toasting, Drying, and Cooling system to distill and recapture solvent to reuse, remove antinutritional easing protein to digest by animals, optimize moisture of the meal flakes, and get meal flakes to ambient temperature.
    - Sizing: The meal is conveyed to ensure corrected size.
    - Evaluation: Testes for levels of fiber, residual fat, etc are conducted.
- Oil
    - Stripping: Oil is stripped from the extractor in the form of micella.
    - Distilling: Solvent is removed from the oil
    - Refining: Lecithins are removed, and the oil is classified as degummed soybean oil. The gums are added back for energy or used in commercial products.
    - Deodorizing: Odors are removed.

One ton of soybean produces a 78/19 process, which means, 780 kg of soybean meal and 190 kg of soybean oil (Stonex, 2022). The process lead time can vary from 30 to 60 minutes depending on the characteristics of the grain (Siqueira, 2014).

The soybean industry has faced changes in its production process due to stricter environmental and economic criteria; hence, the operation needs to comply with stringent

environmental rules while improving process efficiency for both operational costs and product quality (Demarco & Gibon, 2020).

3. Evolution of the Soybeans Supply Chain

There is a lot of controversy on soybean origin and domestication. It is widely believed that the modern soybean originated in East Asia 6000–9000 years ago, but its domestication has been considered a mystery due to a lack of molecular studies and archaeological information (Carter et al. 2004; Sedivy et al. 2017).

Soybean has been consumed in Asia for thousands of years as tofu, soy sauce, soy milk, or other processed soybean foods and were only introduced in other parts of the world in the 19th century, more specifically in North America as an alternative oil source (Ali et al. 2022; Thrane et al. 2017).

The origin of cultivation of soybeans is established in China around 1,100 BC and spread to Japan by the first century AC. As mentioned, soybean became an important crop in the U.S. and Canada between the mid-19th to early 20th centuries and World War II kindled the prosperity of the grain as the drastic increase in demand for lubricants and oils (Chang et al. 2015).

At almost the same time soybean was introduced in South America where commercial-scale production started in Brazil in the 1940s and in Argentina in the 1960s. However, it was after the 1990s that production has been rapidly increasing in North and South America where the U.S., Brazil, and Argentina became the top players in the production (Chang et al. 2015).

The reason for this growth in production is related to the situation in China. Since the end of the 1970s, China has been growing at an unprecedented scale in industrialization, the Gross Domestic Product (GDP) per capita, and urbanization, provoking changes in diet and food consumption patterns (Sly 2017). The rising demand for soybeans in China was not viable to attend only for local production expansion, hence, the American continent seems the perfect

place due to territorial farm extension, climate, and production and transportation costs. Ali et al. (2022) point out that due to land and water resource limitations, China depends on the international market to maintain a stable soybean supply, and the country consumes more soybeans than anywhere in the world and at any time in history.

Another aspect essential to highlight is that the 1990s coincided with the growth of industrialization in China, and the American continent is one of the most important destinations for Chinese products in areas such as plastics, electronics, equipment production, raw materials and so on. Thus, we have a balance in trade between countries. However, this balance provokes a dependency for both sides, generating a discussion from one side regarding deindustrialization and from another regarding food dependency. Currently, China is making movements to buy soil in Africa and South America to control production. Another step is to advance in the Trading sector with Cofco company raising the participation in the production market.

The soybean supply chain is a complex that not only generates significant economic value but also brings about critical environmental and social implications (Jia et al. 2020). The land available for growing soybeans is limited, and deforestation is a significant concern in Brazil, Argentina, and China.

4. Logistics Processes

The logistics process of soybeans commences in the field. After the crop is harvested, the machinery loads trucks directly on the farm, Figure 2. The pipe from the combine harvester is filling the truck.

Figure 2. Soybean loading in the field in Mato Grosso State, Brazil. Source: Authors

Afterwards, there are some possibilities for transporting the harvest by truck:

- Transport for storage: The trucks transport the grain collected to storage areas in the property, in cooperatives' storage systems, and in elevators, Figure 3. The idea is storage to mix grains properties to control moisture and remove foreign materials, hulls, and weed seeds. International standards for soybean delivery are 14% moisture and 2% foreign materials. In the transport, a 0.25% difference is acceptable between the truck cargo weight at the beginning and the end of the journey.

Figure 3. Soybean Garner. Source: Authors

- Transport for intermodal terminals: The grains are transported to terminals where they will transfer to storage areas and will be loaded on railroad transport or waterways systems, Figure 4.

Figure 4. Intermodal Soybean Terminal in Mato Grosso State, Brazil. Source: Authors

- Transport to Ports: In some cases, the trucks or trains can be loaded directly to the Ports, parting from the farms or storage areas.

Usually, soybean is grown far from the ports (see Figures 5, 6, 7) which impacts logistics costs. Due to this fact, transport modes with great capacity are recommended, such as trains or waterways.

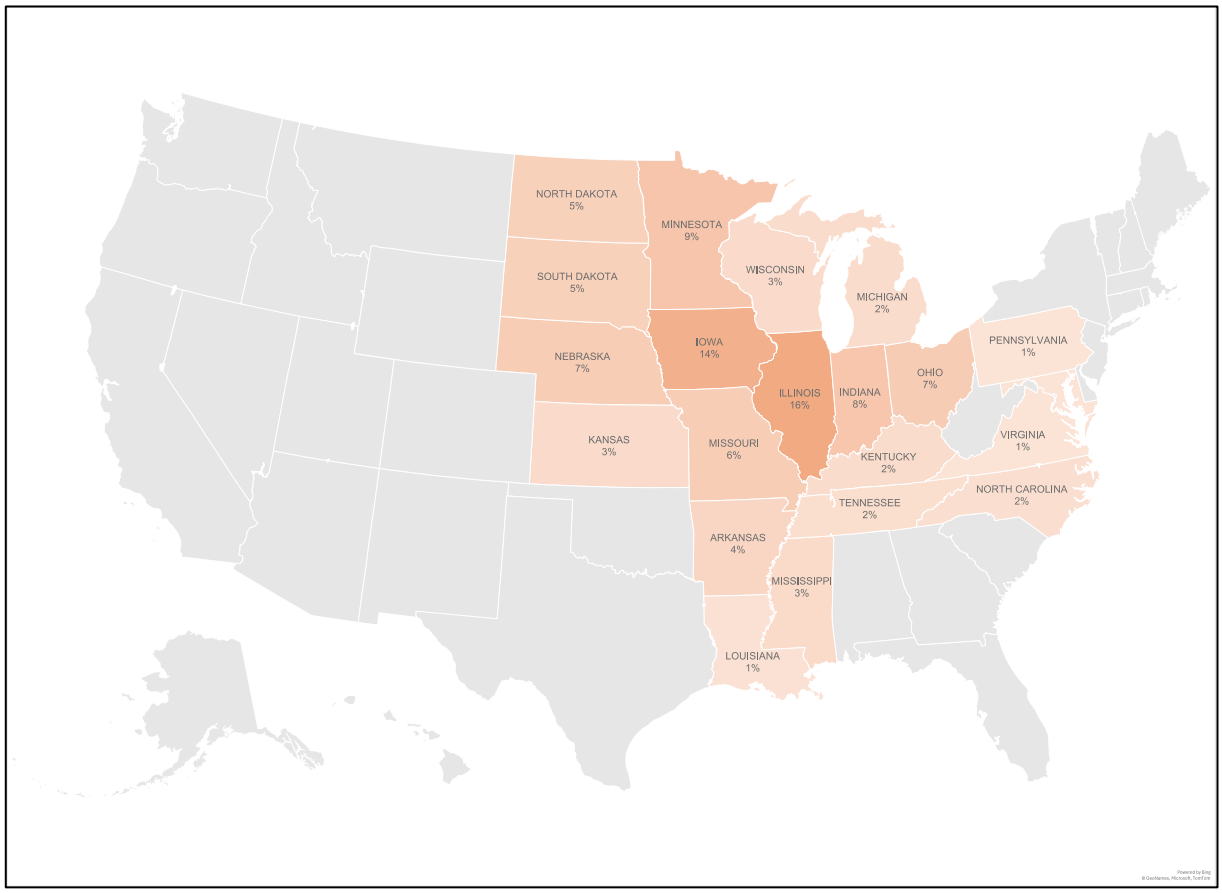

Figure 5. Soybean Production in the US per state. Source: Authors using data from USDA (2024) from 2023 production in metric tones

As can be seen in Figure 5, soybean production in the USA is significant in the middle (e.g., North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Wisconsin, Illinois, Indiana, Ohio, as well as parts of Arkansas and Mississippi and at some locations such as Virginia and North Carolina on the East Coast).

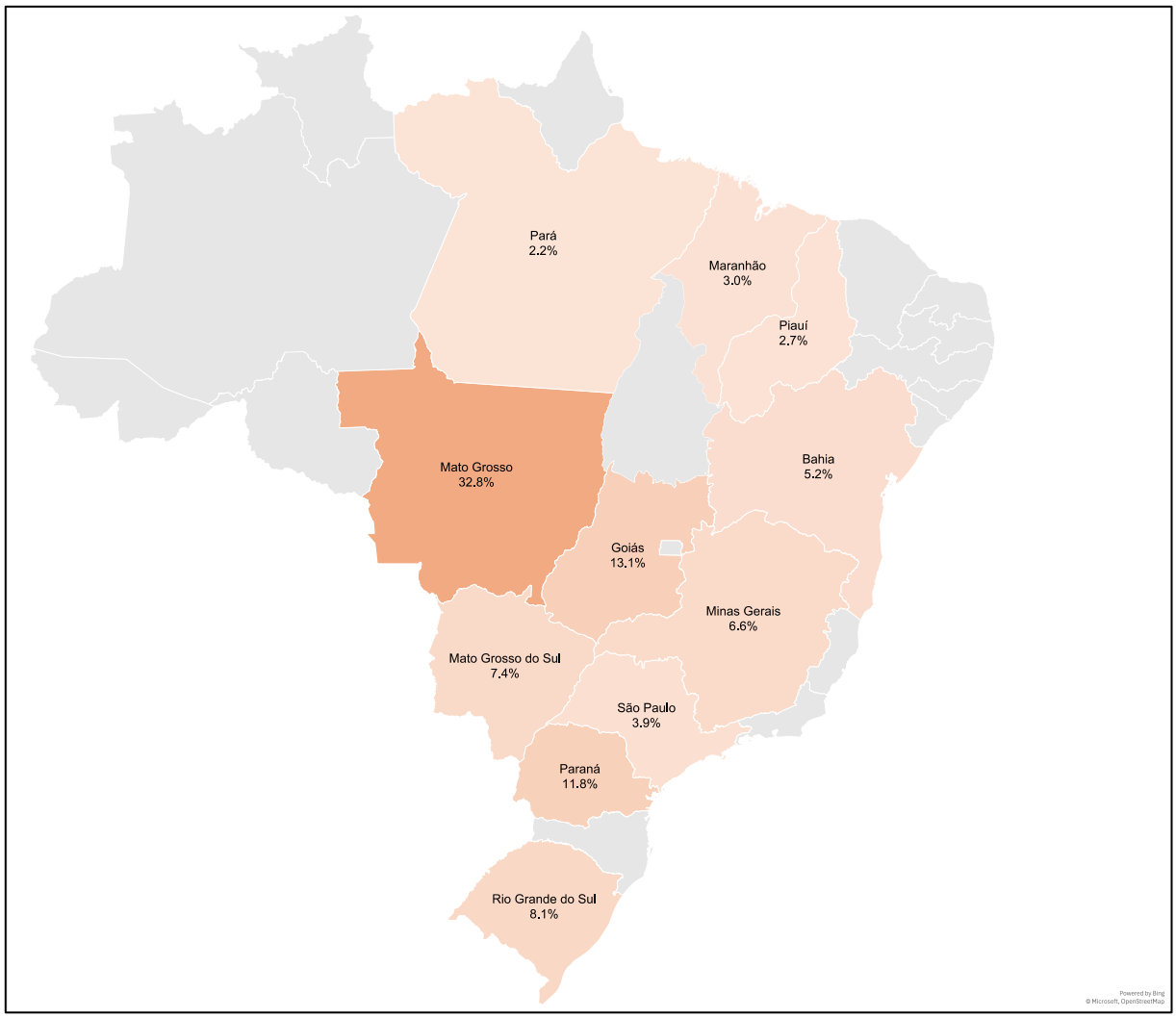

Figure 6. Brazilian Soybean Production per state. Source: Authors using data from IBGE (2024) from 2022 production in metric tones

Figure 6 shows that the soybean belt in Brazil is the strongest in the Mato Grosso, with a significant presence in Parana, Rio Grande do Sul, Goiás, and Mato Grosso do Sul. For Argentina in Figure 7, Buenos Aires and Cordoba have almost 60% of the production.

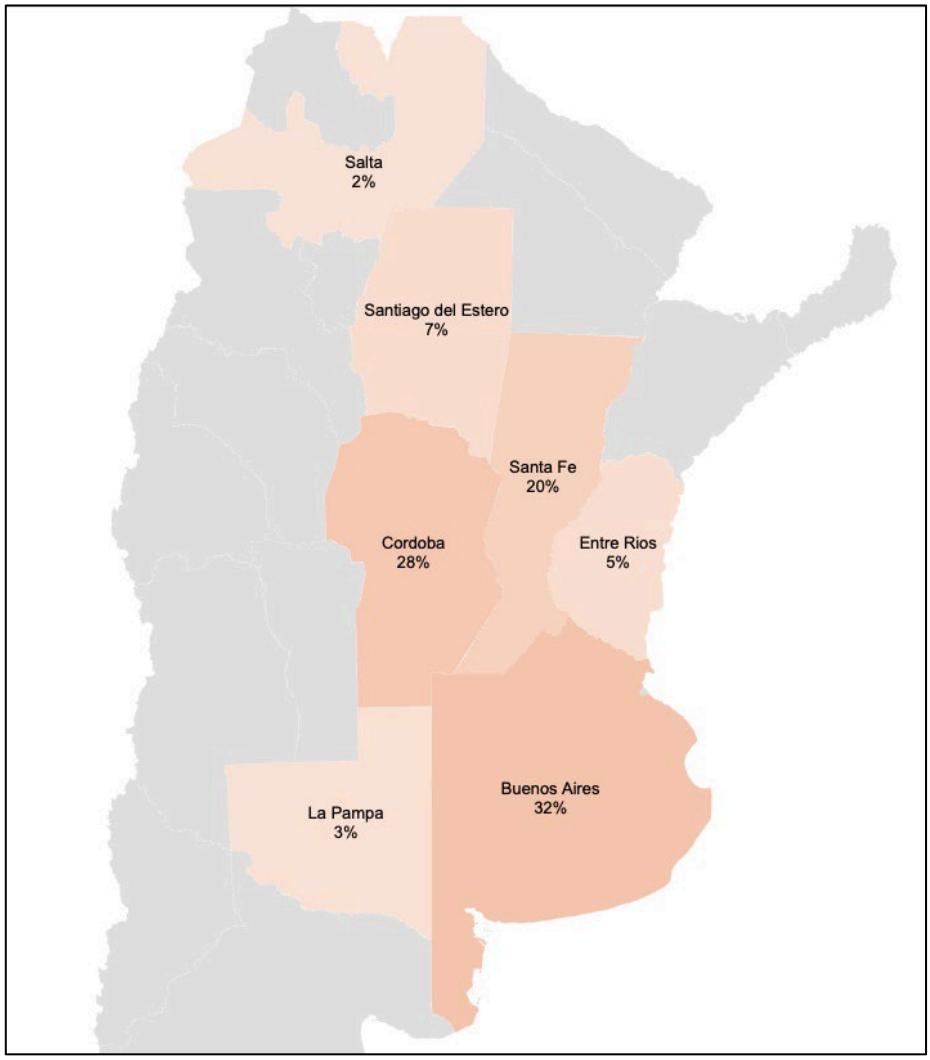

Figure 7. Argentina Soybean Production per province. Source: Authors using data from Secretaria Bioeconomia Argentina (2024) from 2020 production in metric tones

Transportation overseas is made by bulk ships, which are also referred to as dry bulk carriers. An image can be seen in Figure 8. These ships have large holds that are filled with soybeans after they are dried to a moisture content of 8% to 10% to minimize spoilage.

Figure 8. Grain loading in Bulk Carrier in Port of Santos, Brazil. Source: Authors

The transportation costs can vary. As an example, the cost of transporting Brazilian soybeans produced in the North of Mato Grosso state from the southern ports to Shanghai, China was USD 75.49 per metric tonne (MT) in 2016 and USD 59.30 per MT in 2021 by truck. Note that despite domestic freight reduction in USD due to the devaluation of the Brazilian Real (BRL), it increased in the local currency from BRL 263.32 on average to BRL 315.50 provoking impacts on producers' revenue.

The ocean freight was USD 16.63 per MT in 2016 and USD 53.40 per MT in 2021 (Salin, 2022). The rise in ocean transportation costs is related to the changes in procedure due to the COVID-19 pandemic. In addition, the rise in demand provoked an increase in international stocks.

Regarding the use of the railroad for domestic transportation, in 2021, the cost was USD 29.90 per MT. However, there is a cost of truck transport between the farm/storage area to an intermodal terminal that is around USD 20.64 per MT. Thus, comparing the total cost of domestic transportation, we have USD 59.30 per MT against USD 50.33 just 8.5 % less. In this period, soybean MT price increased from USD 331.91 in 2016 to USD 482.47 in 2021 (Salin, 2022).

As a level of comparison of increasing rates considering the two main exports Brazil and the United States considering the Department of Agriculture United States database, we have in September 2022 a difference of total cost of transportation between Minneapolis/USA and Shangai/China (domestic and maritime freight) and North of Mato Grosso/ BRA and Shangai/China of 13% (USDA, 2023d), Figure 9.

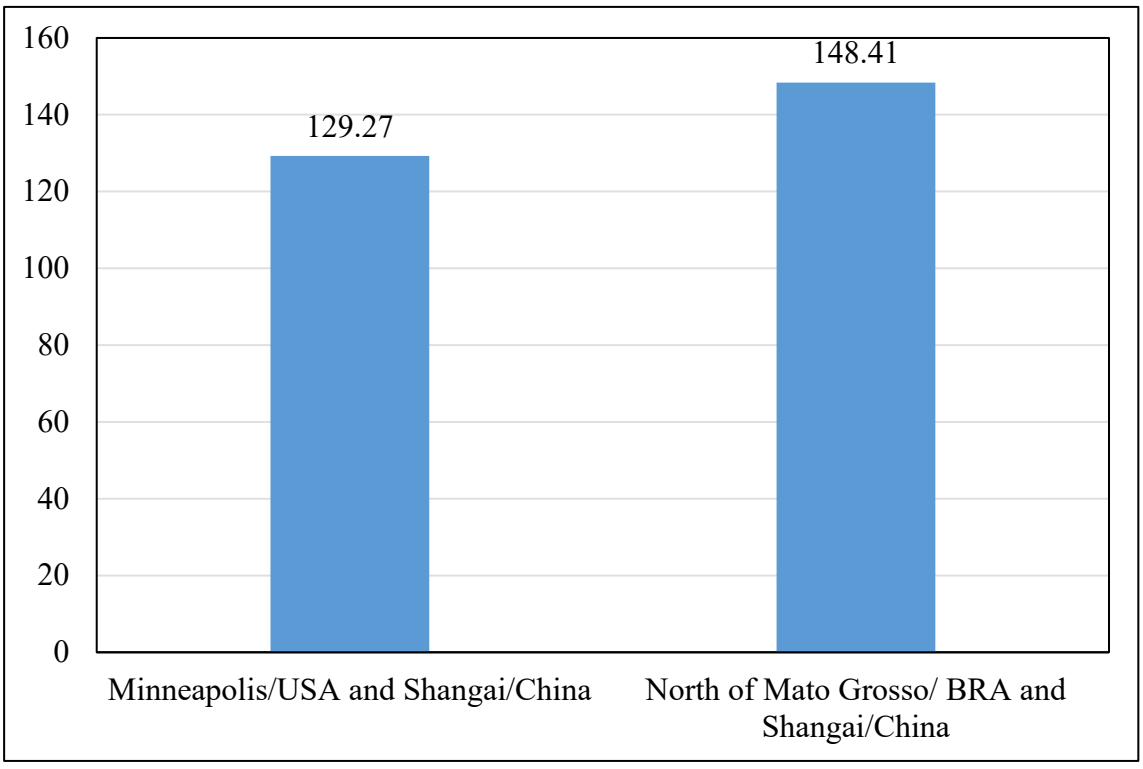

Figure 9. Comparison of Soybean Transportation Costs: the US vs Brazil (Data Source: USDA, figure drawn by authors)

The main difference between countries is in the logistics due to the domestic infrastructure. The US use elevators connected to waterways, reducing the use of truck inside the farms, while in Brazil the intermodal railway terminal is around 600 km from the North production pole of the state. In Brazil, the use of waterways is sparse, due to limitation of availability – the main source of electric energy in Brazil is based in DAMs, and for this reason, there is a lot of control of the river uses and consequently a prioritizing to use of them to energy production. Moreover, it is not possible to use waterways without complementary transportation as well as the railroad system.

5. World Trade

The international production and exports of soybeans are a very concentrated market, where the United States, Brazil, and Argentina are highlighted as the main producers, and China is the main market (dos Reis & Machado 2022).

In the 2021/22 harvest year, the soybean world production was 359,767 thousand MT: Brazil was the first place with 130,500 thousand MT, and the US second with 121,528 thousand MT. Argentina is in third place with 43,900 thousand MT, China is fourth with 16,395 thousand MT, and India is fifth with 11,889 thousand MT (USDA 2023e).

Regarding the importers in the same crop year China is the main market with 99,740 thousand MT, European Union in second with 14,549 thousand MT, Argentina in third with 3,839 thousand MT, Mexico in fourth with 5,956 thousand MT, and Thailand in fifth with 3,243 thousand MT (USDA 2023e).

Considering exports, Brazil is the leader with 79,063 thousand MT, the United States with 58,721 thousand MT is in the second position, Paraguay is in the third with 2,273 thousand

MT, Canada in fourth with 4,284 thousand MT, and Argentina in fifth with 2,881 MT (USDA 2023e).

First, Brazil and the United States are the main producers and the main exporters. China is demanding around 60% of soybeans exported worldwide. Argentina is a big producer but, at the same time, a big importer. This does not mean an enormous demand but shows the impact of two things: the oil industry is important for Argentina, which exports the majority of its production to India, and second, the currency in the country is highly devaluated in relation to the dollar, making exportation an attractive business to producers and creating product shortages inside the country for oil and cattle production.

5.1 Network analysis of significant exporters and importers

Brazil and the US (USA) are the main producers in the soybean market and always competing for the first position. For this reason, we compared the export market by considering Grain, Oil, and Meal with three different networks (one for each type). We adopted a five-year period (2018 – 2022) to avoid seasonality and reduce fluctuations. The networks were plotted using UCINET 6 for Windows and NetDraw 2.097 from Analytic Technologies. The data were obtained from Brazil's Foreign Trade Department and Foreign Agriculture Service from the Department of Agriculture of the United States. The data capture the exports to the top 20 partners of each country in each segment. Figure 1 shows the Soybean Grain Network where the thickness of the line indicates the amount of flow from the originating country to the receiving country.

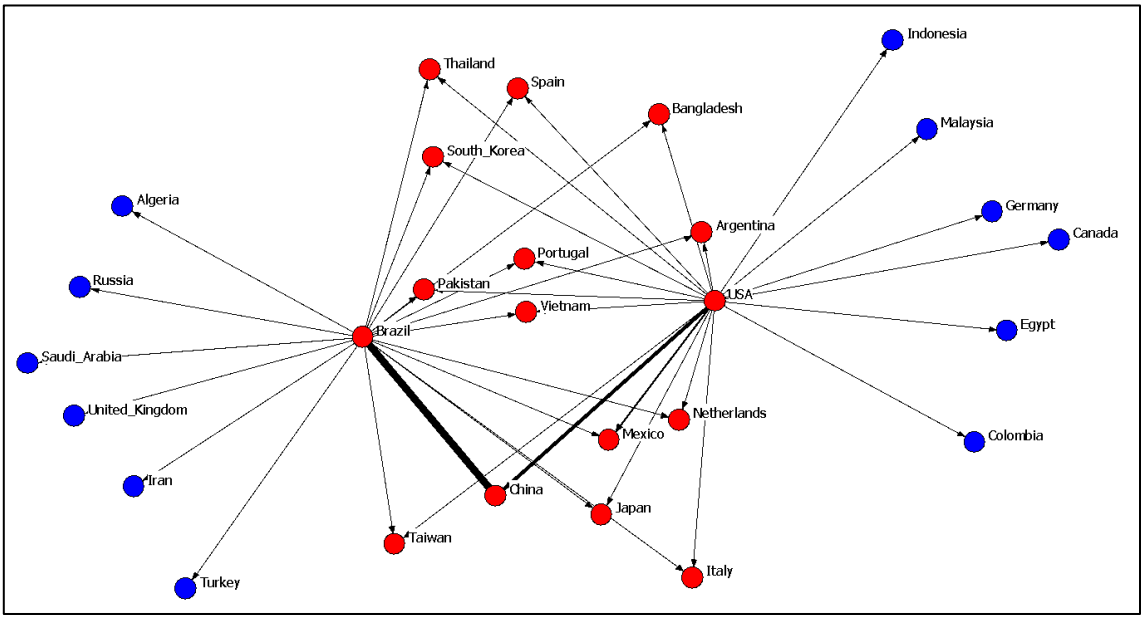

Figure 1. Soybean Grain Network (Source: Authors)

As can be seen in Figure 10, the countries in the middle of the network (in red) are buyers from both countries. China is the main buyer player in both cases confirming the numbers presented in the World Trade topic. Figure 11 presents the Soybean Oil Network.

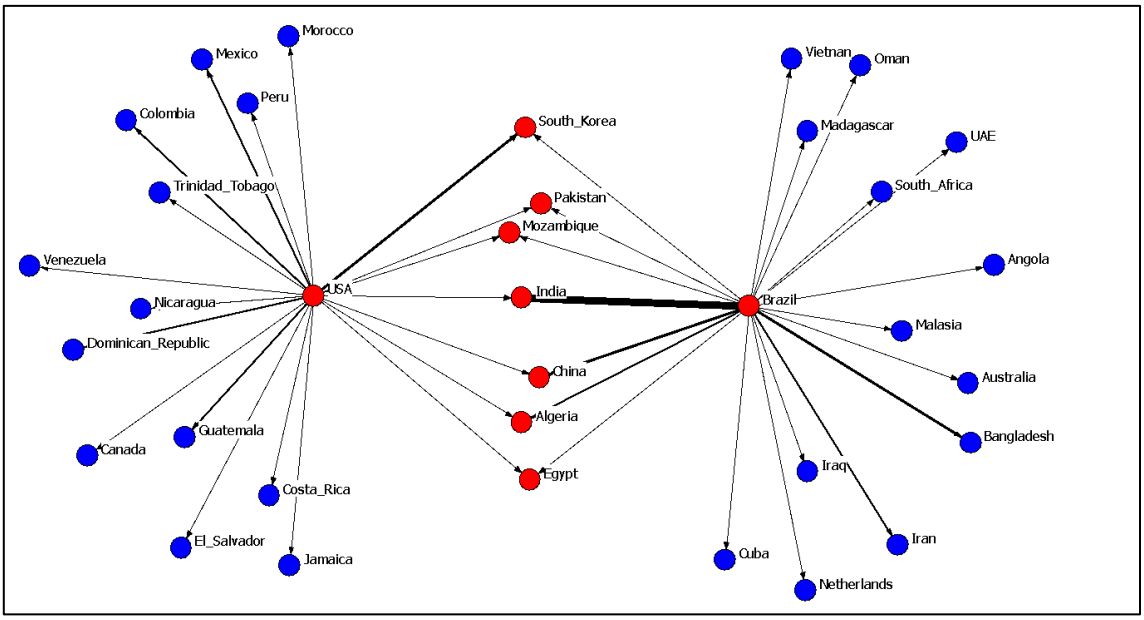

Figure 2. Soybean Oil Network (Source: Authors)

Regarding Soybean Oil the major buyer is India rather than China. Both countries have the major world population. However, China buys grains because the Chinese have a developed soybean industry while India requires the import of oil. Due to that, it pays more for the product and does not obtain the benefits of crushing that is the Soybean Meal to animal feeding. Figure 12 shows the Soybean Meal Network.

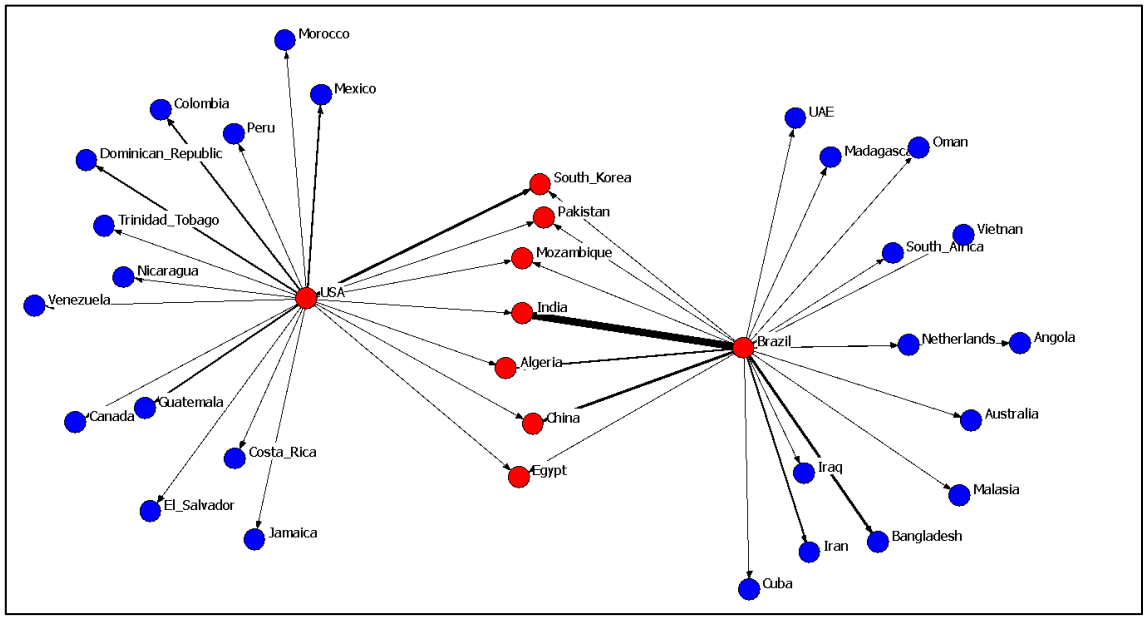

Figure 3. Soybean Meal Network (Source: Authors)

The same typology can be seen here; however, fewer partners are buying from both countries. At the same time, the US attends to the demands of neighbors while Brazil has connections with Asian and African countries. Exceptions are that Cuba in Latin America (not commercialized with the US due to political reasons), the Netherlands in Europe, and Australia in Oceania. Moreover, although the US and Brazil export to common countries, the US has a stronger partnership with South Korea, while Brazil with China and India. The fact that three countries belong to the BRICS may affected this scenario. On the other hand, the US and South Korea historically have stronger political relationships.

5.2 Network analysis of significant exporters and importers

Commodity prices reflect both demand and supply factors, and how some of them are storable, like those of financial assets, their prices reflect both current and expected future demand and supply conditions (Matsumoto et al. 2023). This is the case with agricultural commodities.

In the last decades, it is possible to note an increase in commodity prices pushed by growing economies such as China (Lyu et al. 2022). As noted in the last topic China is the main market for soybean production and their effect can be observed in the product price. Between 2016 and 2021 the price of the soybean produced in the North of Mato Grosso state in Brazil has increased from USD 331.91 to USD 482.47 per MT (Salin 2022).

If we considered the total export market of the US soybean production in 2022, of USD 34.39 billion and a volume of 57 million MT China represented USD 17.87 Billion, around 52% of the country's exports. In Figure 10, it is possible to verify the changes in soybean commodity prices produced by the US (USDA 2023f).

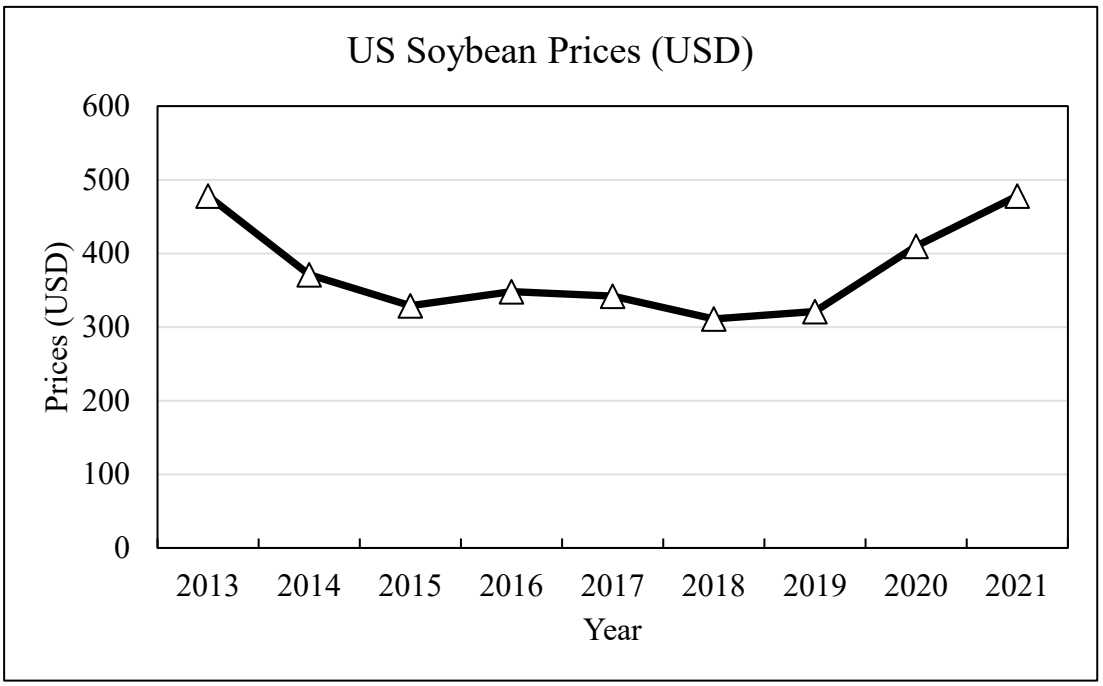

Figure 4. the US Soybean Prices Evolution. Source: Authors developed using data from FAOSTAT (2023)

The increase in commodity prices has a direct impact on soybean flow mainly for developing countries. These countries have been struggling to avoid the devaluation of their currency against the dollar. Insofar as this devaluation increases, the exports rise and impact internal marketing. Considering that soybean has an important impact on supply chains of animal production the rise in export volumes has a direct impact on those chains. Therefore, many times, countries need to reimport the grain, impacting the final prices of those products.

6. Environmental impacts

As a commodity, soybeans are produced by five major countries, as analyzed above, and consumed worldwide. Since it became a commodity in the 1970s, the environmental impact of soybean production has started to be visible (da Silva et al., 2021). Serious environmental consequences of increased soybean production include changes in land use and land cover. Deforestation is the result of this changing land use and land cover. It is pervasive in Brazil (de Silva et al., 2023). Other areas that deserve attention are water use, increased or uncontrolled use of pesticides and fertilizers, soil erosions, and greenhouse gas emissions. For example, approximately 69% of the emissions in Brazil and 34% in Argentina are from road transportation (Castanheira & Freire, 2013). Several research centers across the world focus on soybean production, minimizing its negative socio-economic and environmental impacts, and increasing its sustainability.

6.1 Research centers of excellence across the world

Stockholm Environment Institute (SEI) is an international non-profit research and policy organization that focuses on a range of environmental challenges. They collate a significant amount of research on soybeans and sustainability. Some of the topics they address are carbon

footprint, deforestation, and life cycle assessment, featuring papers in Portuguese, Spanish, and Swedish as well.

The International Institute for Sustainable Development, with its head office based in Winnipeg, Canada, issues global market reports for many commodities (e.g., coffee, banana, cotton, palm oil, etc.) including soybean. The Global Market Report on Soybeans (2020, https://www.iisd.org/publications/report/global-market-report-soybeans) argues for voluntary sustainability standards to be adopted and warns that only a mere 2% of production meets these standards. Voluntary Sustainability Standards are issued by the United Nations. They are private standards that require products to meet specific economic, social, and environmental sustainability metrics throughout production and transportation.

World Soybean Research Conference, 11th of which is held in Vienna, is another significant research event to monitor the latest research on the topic. The soybean research is presented in distinct categories as follows:

- Breeding, genetics, genomics, and biotechnology
- Food, feed, and nutrition
- Agronomy, physiology, and agrotechnology
- Weeds, diseases, pests, and their management
- Business and legal, including policy and corporate social responsibility

6.2 Regulations to Curb Negative Impacts

Several regulations exist to curb the negative impacts of soybean production and distribution. Nagoya Protocol is an international agreement that governs the fair and equitable sharing of benefits arising from using genetic resources. It is part of the Convention on Biological Diversity (https://www.cbd.int/), which is part of the United Nations Environment Programme. As of July 2023, 140 countries are party to the Nagoya Protocol

(https://www.cbd.int/abs/nagoya-protocol/signatories/). While Brazil, Argentina, China, and India are among the signatories; the United States of America is not.

7. Conclusions

This chapter presented an overview of soybean production. It is one of the main world commodities and the major oilseed plant. Many uses are possible: edible natural grain, edible oil, protein for animal feed, and biodiesel. Besides that, can be an ingredient for many industrial products.

The world market is very concentrated, and China is the major soybean client worldwide. On the other hand, the production is basically established in the American continent where Argentina, Brazil, and the United States appear as the main players. The distance between growers and consumers is explained by climate conditions, the history of cultivation of the grain, and low logistics cost in comparison to the production process and risks. In this chapter, it was possible to understand these reasons at the same time showed the steps of this international trade.

The matter is not complete in this chapter, and other materials should be studied. The authors suggest not only investigating other external literature as well as to explore the other chapters of this book to get a complete idea regarding the soybean industry.

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