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Impacts of Brazilian Green Coffee Production and Its Logistical Corridors on the International Coffee Market

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Abstract: *Background:* The coffee industry is one of the most important world supply chains, with an estimated consumption of two billion cups daily, making it the most consumed beverage worldwide. Coffee beans are primarily grown in tropical countries, with Brazil accounting for almost 50% of the production. The objective of this study is to examine the Brazilian trade between 2018 and 2022, focusing on state producers, logistical corridors, and importer countries. *Methods:* The methodology approach revolves around a quantitative method using Social Network Analysis measures. *Results:* The results reveal a massive concentration in local production (99.5%—Minas Gerais), port movements (99.9%—Santos, Itaguai, and Rio de Janeiro), and country buyers (80.9%—the United States, United Kingdon, and Japan). *Conclusions*: The study concludes that the Brazilian green coffee supply chain relies on a fragile and overloaded logistical network. Due to that, this study indicates that the stakeholders and decision-makers involved must consider this high concentration of production in some areas and companies. They must also address the bottlenecks in logistical corridors and the fierce competition involved in acquiring and processing Brazilian coffee production because these factors can drastically affect the revenue of the companies operating in this sector.

Keywords: coffee trade; logistics; international marketing; agriculture globalization

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1. Introduction

Coffee is the most consumed beverage worldwide, with approximately two billion cups served a day [1]. The European Union, the US, and Japan are the primary coffee-importing countries, accounting for 65.6% of the total, while Brazil, Indonesia, and Ethiopia are the main exporters, accounting for 61.6% (Brazil only 44.6%) [2]. Coffee production is concentrated in those countries due to edaphoclimatic conditions [3].

Brazil has an extensive agricultural area and uses only 8% of it [4]. About 25% of the country's GDP comes from agribusiness [5]. The country is a major world exporter of grains, fruits, and cereals [5], standing out in the world scenario of green coffee exports [6], where an increase in movement is expected [7]. The estimated global production of green coffee for the 2022/2023 crop year was 171.3 million bags of 60 kg, which is 1.7% higher than the previous crop year production [8].

Several studies have been conducted regarding Brazilian coffee production and international market trade. The Brazilian Institute of Geographic and Statistics [9] studied the dynamics of coffee production in Brazil between 1975 and 2013, identifying the logistics process of Brazilian coffee exports. Costa [10] investigated the Brazilian specialty coffee

scenario, where he defined the concepts of the coffee supply chain, Brazil's situation related to the global market, and the different local regions of production. Barros et al. [11] analyzed the relationship between coffee exports and machinery imports in Brazil from 1869 to 1939 and suggested that foreign exchange revenues from coffee exports were important for the onset of industrialization, as machinery imports served as a proxy for real investment demand. Barbosa et al. [12] studied the insertion of Minas Gerais and Brazil in the Coffee Global Value Chain (CGVC), exploring data from international and regional trade. They identified opportunities to strengthen Minas Gerais's position by assuming the roasting process and boosting special coffee production. Nevertheless, we did not find studies relating to Brazilian state producers, logistical corridors, and importer countries. How do the coffee exports work? What are the main consumer markets of Brazilian coffee? Is there a concentration or it is spread among many countries? Are there logistical bottlenecks affecting the international coffee trade?

The objective of this paper is as follows: (1) to investigate Brazilian green coffee exports between 2018 and 2022 in order to identify state producers, logistical corridors based on cargo ports, and international importer countries; (2) to point out the relations among them and the reasons that led these actors to these main roles in the network. We adopted a five-year period in this study to avoid missing data or trade seasonality.

The methodology revolves around Social Network Analysis (SNA), which is a research method that involves graph theories, probability theory, and geometry to generate network connections regarding actors' relationships [13]. Relationships in a network can be measured through the volume of transactions between nodes. Several types of transactions can be measured as information, data, and currency. One way to analyze these relationships is through social media analysis [14]. To do SNA analysis, we adopted UCINET® 6.738 and NetDraw® 2.178.

The research questions that this paper intends to respond to are as follows:

RQ1. Which countries are the main consumers of Brazilian green coffee and why?

RQ2. What are the main logistical corridors of Brazilian green coffee exports and the ports involved?

The document is organized as follows. This section introduces the main ideas of the paper. Afterward, we investigate the coffee literature and the evolution of its production. Further, we present the materials and methods adopted. After that, we show the findings and answer the research questions using the results and literature. Finally, we point out the conclusions obtained from the research.

2. Background

The origin of the word coffee has some controversy. Some consider that the word originates from the Turkish word Kahwa (or qahwah), which means strength. Other researchers believe it is derived from the Turkish word Kahweh and its meaning is associated with the sub-shrubby wild lineage plant [15–17]. However, several languages have the same etymology for one of the most consumed beverages in the world: *Café*—Portuguese and French, *Coffee*—English, Cafe—Spanish, *Caffè*—Italian, *Kaffee*—German) [18].

The origin of the coffee tree is also uncertain and there are various legends about it. The most widespread is that of the Ethiopian shepherd Kaldi who observed that his animals became agitated after consuming leaves and beans from the coffee plants [19]. However, the most plausible story revolves around the Islamic pilgrims from Ethiopia who used the seeds of the coffee tree to become more active during pilgrimages to Mecca [20–22]. The conclusion about these various legends leads to the discovery of the coffee drink and its effects on organisms. Another important aspect refers to the beginning of coffee consumption. It was ingested as a fermented food or drink from the pulp of the fruit, and, by accident, the bean was roasted and gave rise to the drink that is consumed today [20,23].

The consumption of coffee was related to the slave trade that used the bean to support long walks, with the possibility of the germination of seeds along the way [19–21,24]. In

addition, the prohibition of the consumption of alcoholic beverages by Islam led to the widespread planting and consumption of coffee fruits, especially in Turkey [20,21].

Also, it was in Turkish territory that the processes of roasting the beans and grinding them into fine powder arose. The ground coffee was boiled for a few minutes and decanted to be served; the use of spices such as cloves and sugar completed the drink that was drunk in familial and social interactions [21,25]. This consumption caused specialized businesses to emerge in Europe, both for the commercialization of beans and for the sale of the drink [19,21].

In the United States, consumption was consolidated in New York in 1732 with the creation of a large coffee market called the Exchange Coffee House of New York. It was later replaced by Merchant's Coffee House [19,26].

In Brazil, consumption spread in the early eighteenth century, with the first seeds planted in the northern region of the country. In the same manner that occurred in Europe, the consumption of coffee drinks was widespread, and, soon, the first plantations appeared. The climate and relief conditions of the southeast region were evident and, until today, it is recognized as the ideal condition for planting [21,24,27,28].

Coffee growing is one of the oldest agricultural explorations in Brazil, and, between the last quarter of the 19th century to the first three decades of the 20th century, elevated this crop to the status of the country's main export commodity [9].

Coffee production in Brazil was first established in Rio de Janeiro [10]. In 1820, it was transferred to the states of Sao Paulo, Minas Gerais and Parana [10]. Sao Paulo was the main producer until 1969, when Minas Gerais took the position due to the decline in coffee production in the state for other kinds of agricultural commodities [10]. Many producers moved from Sao Paulo to the south of Minas Gerais, seeking low-priced ground and an adequate climate for coffee production.

Another reason for that are the public policies such as Coffee Plant Renewal and Reinvigoration Plan organized by the Brazilian Coffee Institute—IBC [9]. The IBC was an authority tied to the Ministry of Industry, International Commerce, and Services between 1952 and 1989 [29].

The agroclimatic zoning closes the cycle of coffee farming conditioned by natural factors that, especially in the west of Sao Paulo, established the idea of the use of fertile soils in a more complex cycle involving the locational constraints of coffee growing [9].

Finally, the most economically important genus of coffee is *Coffea*. Its cultivation is widespread in tropical countries, both for consumption in the domestic market and for export [18,30–32]. The genus *Coffea arabica* and *Coffea canephora* are responsible for about 99% of the world's production [18,19,21,26,31,32].

3. Materials and Methods

To answer the objective proposed in this paper, we conducted exploratory research regarding the exports of Brazilian green coffee based on state producers, importer countries, and logistical corridors. The proposal was to analyze how the export network works, taking into account that the country is the biggest world producer and exporter of this kind of coffee [29].

3.1. Data Collection and Treatments

We collected data from the Brazilian Foreign Trade Portal provided by the Ministry of Development, Industry and Foreign Commerce [33]. The data were obtained from the Siscomex System which registers all the transactions of international trade. A five-year period was adopted from 2018 until 2022. A higher period could create disturbance due to changes in logistics operations, and a small one could create a bias that could affect the use of the results as an exploratory analysis.

The data were treated using Microsoft Excel® v.19. Data values were processed linking the relations in volume among state producers, ports, and importer countries. Besides that,

only significant relations were considered (volume equal to, or higher than, 100 Metric Tons). Descriptive statistics of the data can be seen in Table 1.

Table 1. Descriptive statistics.

Variable	Observations	Mean	Std Deviation	Minimum	Maximum
Volume	1863	742,850	13,705,098	100	482,948,396

3.2. Data Analysis

The data analysis was conducted by adopting the Social Network Analysis (SNA) approach. SNA, in a very simple way, is interdisciplinary research that aims to predict the relationships between the actors and the impact of these relations on the whole process [34]. To address this type of social network, statistical methods are the most used, and there is support in the literature for this [34]. Those methods can group priceless information from a network produced based on a data set [35].

The social network method proposes several measures like network centrality, k-core, and tie strength relationship. Firstly, the network centrality unfolds in degree, closeness, and betweenness [36]. The centrality degree shows the involvement of a node in the network based on a measure of immediate adjacency shown by the number of ties that a given type of node has [37].

The measures of centrality are understood through a set of concepts that are related to the contribution of the node to the structure of the network [35]. Therefore, centrality can be considered a structural node [38] and the interpretation is conditioned on the importance and type of data analyzed. In the analysis of social networks, the central nodes are interpreted as the most influential or leaders [39], or even have greater autonomy, visibility, or involvement [35].

Another very common measure of the SNA method, adopted in this work, is the k-core. It converges in a subgraph where each actor has a degree k or greater than the other actors in the subgraph. Each K network is equivalent to a relation of the actor. One criterion that can be used to shrink the nodes in a complex network is k-core analysis, focusing only on the most relevant ones [40].

The most relevant aspect of these relationships between actors is the volume of transactions. It is possible to use information exchange, monetary value, transferred load, and so on. The analysis can be performed through volumes in a table or, more deeply, through a plotted graphical network. When looking at the network, the lines represent the connections between the nodes. The thickness of the line can indicate the strength of the connection between the pairs [41], the frequency of interaction [42], or the volume of the connection [35].

To perform SNA measures, we adopted UCINET 6.738® and NetDraw® 2.178 to generate the graphical analysis. Thus, databases were imported to UCINET; we ran degree centrality (in and out) as the main analysis and the k-core and betweenness centrality as a sensitivity analysis. Moreover, the data were also imputed to NetDraw® 2.178 to produce the graphical analysis of SNA.

4. Results and Discussion

4.1. Main Analysis

Degree centrality in SNA analysis refers to the number of connections that one node has. It represents the actors/nodes at the center of interactions in the network [43]. Freeman [44] points out that a node located at the center of the network is assumed to be structurally more central than any other node and does appear to be in some special position related to the overall structure.

The degree centrality of our data can be seen in a graphical form in Figure 1 and specified as the number and volume of interactions in Tables 2–5—indegree (entering in the node) and outdegree relations (outing of the node).

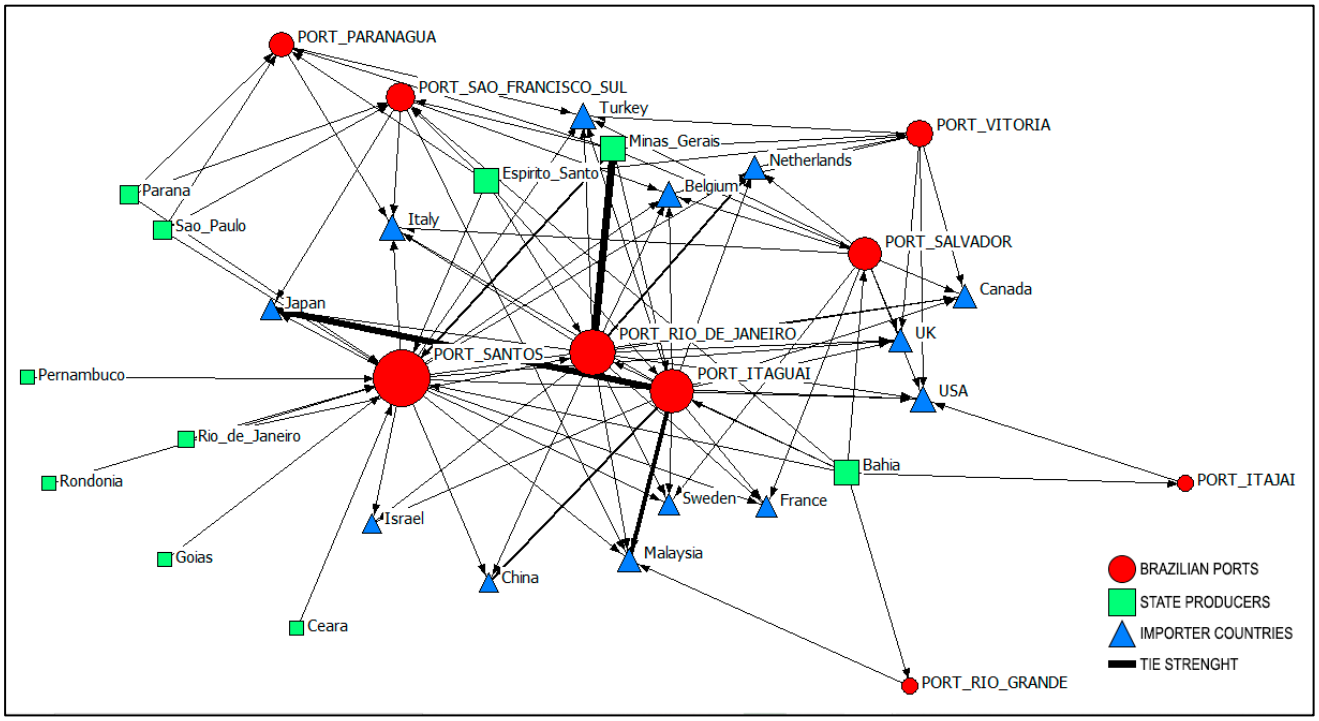

Figure 1. Degree centrality of the Brazilian green coffee exports network.

Table 2. Port outdegree.

Actor	OutdegV (MT)	OutdegN (Qty Relations)
PORT_SANTOS	754,477,440	13
PORT_ITAGUAI	332,680,160	13
PORT_RIO_DE_JANEIRO	233,739,616	13
PORT_VITORIA	121,795	6
PORT_SALVADOR	116,090	9
PORT_PARANAGUA	44,544	2
PORT_SAO_FRANCISCO_SUL	3775	4
PORT_ITAJAI	535	1
PORT_RIO_GRANDE	115	1

Table 3. State outdegree.

Actor	OutdegV (MT)	OutdegN (Qty Relations)
Minas_Gerais	1,314,826,240	8
Sao_Paulo	4,281,023	3
Espirito_Santo	1,472,964	6
Bahia	187,293	6
Ceara	96,000	1
Goias	55,197	1
Parana	52,502	3
Rio_de_Janeiro	26,900	2
Pernambuco	194	1
Rondonia	114	1

Table 4. Port indegree.

Actor	IndegV (MT)	IndegN (Qty Relations)
PORT_SANTOS	754,477,440	10
PORT_ITAGUAI	332,494,848	3
PORT_RIO_DE_JANEIRO	233,739,424	4
PORT_VITORIA	121,795	2
PORT_SALVADOR	116,090	2
PORT_PARANAGUA	44,544	4
PORT_SAO_FRANCISCO_SUL	3775	5
PORT_ITAJAI	535	1
PORT_RIO_GRANDE	115	1

Table 5. Country indegree.

Actor	IndegV (MT)	IndegN (Qty Relations)
Japan	671,941,952	4
USA	242,331,216	6
UK	154,446,992	5
Malaysia	96,868,600	5
China	49,165,648	3
The Netherlands	21,915,872	5
France	20,451,906	4
Israel	20,068,654	3
Belgium	15,383,606	6
Canada	9,789,481	5
Italy	9,364,191	6
Sweden	5,626,249	4
Turkey	3,829,673	6

The main ports established a cluster composed of the Port of Santos, Port of Rio de Janeiro, and Port of Itaguai. They have the highest number of connections incoming and outgoing, as well as volume received and exported. They appear as the main gateway of the network. However, our results show a trend, with Port of Santos being the main corridor of coffee exports. Ports of Itaguai and Rio de Janeiro together move around the equivalent of three-quarters of the total coffee exported by Port of Santos, which is the main corridor of exportation.

These three ports are located in the southeast region of Brazil. Together, they move 99% of the green coffee exported. Moreover, they connect all 13 importer countries but only Port of Santos receives shipments from 10 producer states. Considering the degree centrality theory, Santos is the main logistical corridor in volume and connects all the nodes buying or selling green coffee beans from Brazil.

Considering the volume of cargo for a unique country, the Port of Itajai is the most representative, connecting Japan, Malaysia, and the US. Regarding the countries, Asia imported 63%, North America 19%, and Europe 17%. Belgium, Sweden, and the US are the most representative in the network, considering the connections (6 states). However, the biggest in volume are Japan (51%), the US (18%) and the UK (12%).

Coffee has been one of the most popular beverages worldwide since the mid-sixteenth century; the US is the largest country consumer (25 million bags), followed by Brazil (20 million bags) [45]. Considering country groups, the European Union has the highest consumption (42 million bags), while the strongest growth rates are found in Asia and Oceania [45].

Our data analysis indicated that Japan, the US, and the UK were the main destinations of Brazilian green coffee between 2018 and 2022, accounting for 80.9%. According to Conselho dos Exportadores de Cafe do Brasil—CECAFE, considering crop years between July 2018 and May 2023, the Brazilian green coffee exports were 169,273,732 bags of 60 kg [46].

Considering the consumption per capita in the UK and Japan, with a long tradition of tea consumption, it was 3.6 kg, while in the US, where coffee is deeply rooted in consumer culture, the consumption per capita was 4.5 kg [45].

In Japan, coffee occupies a massive niche in everyday life and consumption, and the country is the number three importer of coffee beans worldwide after the United States and Germany [47]. They prefer imported coffee as a grain and roast internally because Japanese coffee equipment is considered to be among the best in the world [48]. Interesting to note is that Japan was targeted in the late 19th century as the country that would start the coffee industry of Brazil [48].

In the United States, the estimated proportion of coffee consumers is 74.7%, representing 154.4 million US adults. In addition, the prevalence of coffee drinking did not differ by sex or general health condition, or by education or household income [49]. Moreover, Erikka et al. [49] conclude in their study that coffee drinking is widespread but varies across categories of age, race/ethnicity, smoking, and alcohol intake, with younger adults, non-Hispanic blacks, never smokers, and nondrinkers of alcohol being less likely to drink coffee than their counterparts.

Raw coffee (green coffee beans) is the single most-traded non-oil commodity in the world because it depends on the geo-location of coffee plantations, soil conditions, management, and specific climatic factors that determine both the quantity and the quality of the beans harvested [50]. Due to that, there is a dependency on the US to import the commodities; the Japanese suffer from the same pressure to maintain the coffee habit. On the other hand, export countries have significant dependence on coffee production and exports, considering the GDP of Honduras (20%), Guatemala (13%), and Colombia (6%) [50]. In Brazil's case, the coffee share of the country worldwide was 33% and represented BRL 34.5 billion [51].

The UK is the fifth largest coffee consumer in Europe, where approximately 95 million cups are consumed daily. Around 181,000 tons of green coffee beans are imported every year to the UK to be processed and consumed, with 66% of the total coming from Brazil, Vietnam, Colombia, and Honduras [1].

Therefore, we can conclude that these countries are the main importers due to the huge internal consumption and efficient local industry that requires raw material (green coffee) for producer countries once coffee production is sensitive to climate conditions. The results aligned with the literature investigation, allowing us to identify an interesting fact; namely, that coffee beverages are also finding ground in cultures with a long history of tea consumption.

From the state producers' perspective, Minas Gerais accounted for 99.5% of the coffee exported using 8 ports, and used the corridor of Santos in Sao Paulo state and Itaguai and Rio de Janeiro in Rio de Janeiro state. The reason why is that the South of Minas Gerais has a high altitude, averaging 950 m, and a mild annual temperature of around 22 °C, with small farms ranging from 10 to 100 ha [10]. However, production is also present in Cerrado Mineiro, where farms range from medium-sized (2–300 ha) to large at an altitude of 800–1300 m, and Chapada de Minas where 80% of the producing farms are smaller than 20 ha [10].

In Minas Gerais, the rural area of the regional capitals of Pouso Alegre and Varginha, in which the Municipality of Guaxupe is included, constitutes the central point of the coffee bean storage network in the Brazilian territory; this function is associated with its strategic position in relation not only to agricultural production areas but also to its access to national and international markets [9].

Located in the city of Guaxupe, the Cooperativa Regional de Cafeicultores em Guaxupe Ltd. a—COOXUPE and the Exportadora de Cafe Guaxupe stand out in the commercialization of coffee at the national and international levels. A focal point in the geography of the production chain and the coffee logistics system in the city of Guaxupe is the presence of the Special Precinct for Export Customs Clearance—REDEX, administered by COOXUPE, which serves to streamline the time necessary for the export of this commodity; it also

contributes to the reinforcement of the safety of this process and avoiding the waste of grains by moving full-load container cargo [9].

Occupying a strategic position along Brazilian roadways, the BR-146 and BR-491, the Municipality of Guaxupe has connections with the Minas Gerais regions of Alto Paranaiba, Triangulo Mineiro, and Southern Minas Gerais, in addition to access to the territory of Sao Paulo and, in particular, its coastline and the port of Santos [9].

4.2. K-Core

The k-core is used to describe network characteristics which the degree distribution is unable to reveal, including the structural and hierarchical properties of the network system [52]. Thus, the Brazilian green coffee exports network can be divided according to its importance, Figure 2.

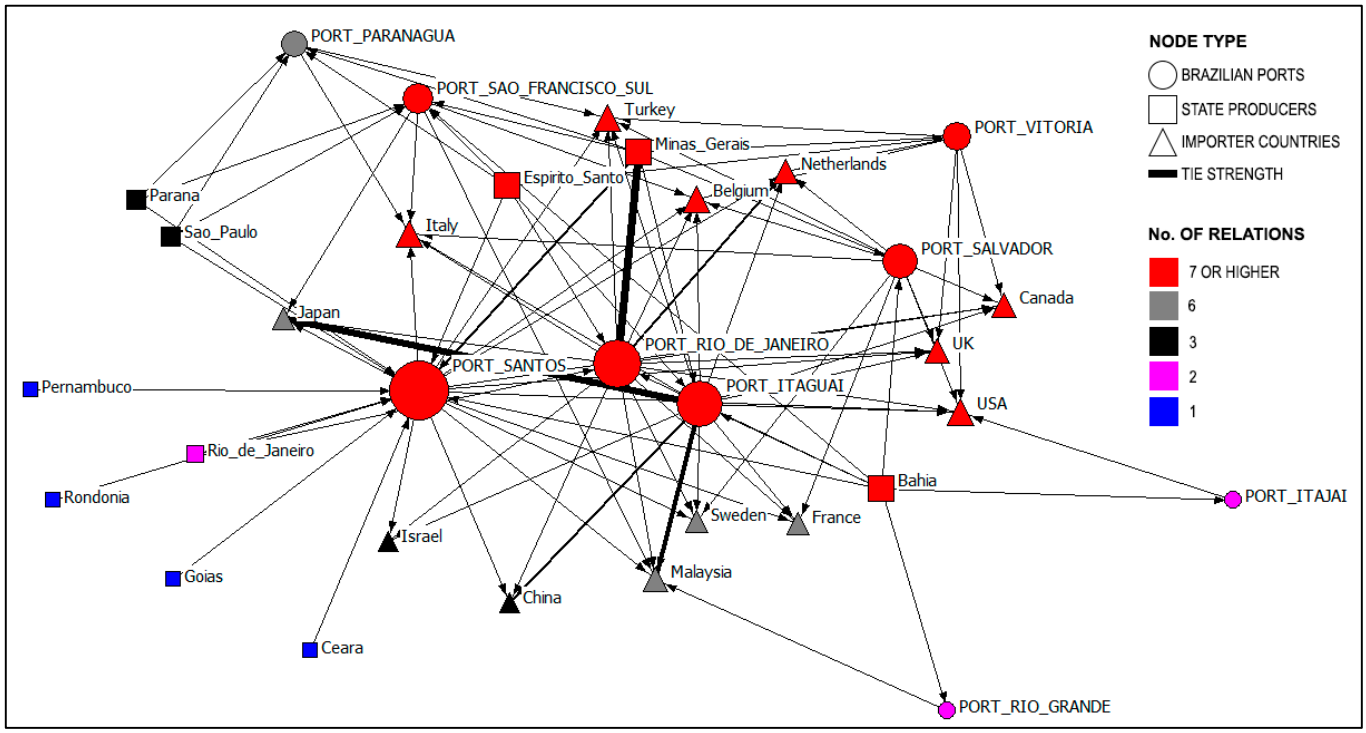

Figure 2. K-core.

The main network is composed of six ports: Santos, Rio de Janeiro, Itaguai, Salvador, São Francisco do Sul and Vitória; seven countries: Italy, Turkey, Belgium, Netherlands, Canada, UK, and the US; and three state producers: Minas Gerais, Espirito Santo, and Bahia. To be part of this main network, a node needed at least five connections in the network. Even Japan, buying 51% of green coffee, only had four connections (grey nodes). Black nodes presented a k-core of three, pink nodes two, and blue nodes one. The size of the nodes is not connected to the k-core analysis; we maintained the structure presented in degree centrality, allowing us to compare both cases together.

Note that five countries are located in Europe and two in North America. As observed previously, the two regions bought 36.5% of Brazilian green coffee. Despite the volume, Japan is not included in the main network in the context of SNA analysis due to its logistics operations being connected to four ports; however, the k-core of four or more allows for the identification of almost all the volume exported and the logistics corridors—94% of the volume.

These results show the importance of analyzing k-core results in connection to the transaction volume. However, interesting results can be seen, including the predominance of rich countries as the main destination of Brazilian green coffee.

From state producers' perspective, Minas Gerais confirms its role as the main source of coffee production in Brazil. Regarding ports, Santos, Rio de Janeiro, and Itaguai confirm their role as transportation hubs for coffee exports.

4.3. Betweenness

Betweenness centrality computes betweenness for a node N by finding all the shortest paths between those nodes and measures how important a node is to the shortest paths through the network [53]. Table 6 presents betweenness results.

Table 6. Betweenness centrality.

Actor	Betweenness	nBetweenness
PORT_SANTOS	88.800	9.548
PORT_RIO_DE_JANEIRO	16.133	1.735
PORT_ITAGUAI	9.633	1.036
PORT_SAO_FRANCISCO_SUL	6.250	0.672
PORT_SALVADOR	3.917	0.421
PORT_VITORIA	2.500	0.269
PORT_PARANAGUA	2.400	0.258
PORT_RIO_GRANDE	0.200	0.022
PORT_ITAJAI	0.166	0.018

Note that only ports have a betweenness centrality degree. Due to this, network centralization is low, at 9.41%. The results confirm the importance of the port of Santos, Rio de Janeiro, and Itaguai as a center of the network. These actors are also called gatekeepers since they tend to control the flow of information between communities [37]; in this case, the volume of cargo between state producers and importer countries.

The same result in degree centrality is presented here and confirms that Brazilian green coffee is exported in a concentrated form. The three ports that respond to the highest number of connections are also responsible for the highest volume.

5. Conclusions

This paper explored the Brazilian green coffee exports between 2018 and 2022, focusing on state producers, logistical corridors, and importer countries. Using data from the Brazilian Foreign Trade System provided by the Ministry of Development, Industry, and Foreign Trade, and a Social Network Analysis approach, the study presented important findings regarding the international coffee market.

Regarding RQ1, our results indicated that the US, the UK, and Japan are the main Brazilian green coffee consumers. The reasons are as follows: (1) the huge market of these countries; (2) their local industries; and (3) the inadequate climate to produce the coffee grain.

Considering RQ2, the results indicated that Minas Gerais is the major Brazilian state producer (99.5%), and it controls the flow of coffee in the three primary corridors of exportation: Santos, Itaguai, and Rio de Janeiro. The reasons are as follows: (1) coffee culture development in the area; (2) climate conditions; (3) efficient logistics involving the reduction of bureaucracy in the export process; (4) proximity to the main logistical corridors of the country in the southeast region.

Despite the advances presented by the Brazilian green coffee chain to Minas Gerais State, Brazil's international trade, and country buyers, the network can be considered fragile due to the huge mutual dependence among actors. Therefore, new studies should be focused on understanding the relationships among networks from the point of view of the companies involved, logistics operators, and market characteristics.

This study is not free of limitations. We considered data from only one source and errors in registration of those data may occur. Moreover, we considered only one type of coffee that may represent a partial holistic perception of the coffee production market and

focus on only one producer. However, these limitations do not affect the character of the exploration of the study to promote insights into these important commodity chains and, consequently, provide relevant information to players.

Finally, the results of the study can provide valuable insights to decision-makers regarding coffee trade with Brazilian producers, based on the knowledge of the places of production, logistics characteristics, and competitors involved. Moreover, the study offers a comprehensive overview of trade marketing based on real data, which can benefit the stakeholders present in this supply chain. Note that the agricultural sector lacks papers and studies that bring to the discussion this comprehensive overview of the logistics process.

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