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Food Supply Chain through Ongoing Evolution

Lessons from Continuous Transformations

Edited by
Karim Marini Thomé, Michael Bourlakis and Patricia Guarnieri

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Contents

About the Editors

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Karim Marini Thomé is an Associate Professor at the University of Brasília, overseeing postgraduate programs in Management and Agribusiness. He is a researcher at the Brazilian National Council for Scientific and Technological Development (CNPq). Professor Thomé acted as a visiting professor at Stockholm School of Economics and Uppsala University (Sweden), working on projects related to the configuration of new actors and elements in supply chains. In a relatively short period of time, Professor Thomé has already generated more than 200 publications in journals, chapters and conferences, and he has been fortunate enough to co-operate with likeminded colleagues, such as Michael and Patricia. He is particularly interested in how new supply chain practices modify the orders of pre-established supply chains and how this change, in turn, generates differentiations in and various versions of supply chains.

Michael Bourlakis

Professor Michael Bourlakis serves as Chair in Logistics, Procurement and Supply Chain Management. He is Director of Research for Cranfield School of Management and Director of the Centre of Logistics, Procurement and Supply Chain Management. He joined Cranfield School of Management in 2013. Previously, he worked at Brunel University Business School (Leadership Roles: Director of Postgraduate Studies for 7 MSc programmes, "Impact" Champion for REF2014, Director of OASIS Research Centre), Kent University Business School (Leadership Roles: Head of Marketing and Supply Chain Management Group, Director of Enterprise), Newcastle University (Leadership Roles: Director of Undergraduate and Postgraduate Programmes), Oxford University Templeton College (Oxford Institute of Retail Management) and Leicester University Management Centre. Professor Michael Bourlakis is an internationally renowned and established authority in logistics and supply chain management, especially in food, retail and sustainable supply chains. He is the recipient of substantial external funding. Specifically, he has won more than 25 research and consulting projects (as PI or Co-I) totaling more than GBP 27.5 million (total allocated project funding) from various bodies (EPSRC, Food Standards Agency, Technology Strategy Board, EU (FPVI, FPVII), Horizon 2020, Marie Skłodowska-Curie), local Regional Development Agencies and private companies. Professor Michael Bourlakis has generated more than 250 publications including 63 journal papers and 3 edited books. He sits on the Editorial Board of 15 journals including leading logistics, supply chain and operations management journals.

Patricia Guarnieri

Professor Patricia Guarnieri earned her Doctorate in Production Engineering at Federal University of Pernambuco and her Master's in Production Engineering at Technological Federal University of Parana. She is an expert in Enterprise Management, teaches graduate courses, hosts MBA courses on these topics, and also holds a Bachelor's in Accounting. She is an associate professor at University of Brasília, Brazil, and acts as a professor and supervisor for the Business Management bachelor course; Master's and Doctorate Program in Management; and Master's in Agribusiness course. She is a researcher at Brazilian National Council for Scientific and Technological Development (CNPq). She acted as visiting professor at Università di Bologna, Italy at the Industrial Engineering Department, working on projects related to the circular economy. She serves as leader in the research group GEALOGS on logistics and supply chain management at University of Brasília, Brazil. She is a member of Scorai Brazil (Sustainable Consumption Research and Action Initiative) and ACPN (Advances in Cleaner Production Network). She participates as chair in the Circular Economy, tracking the main events in Brazil related to logistics and operations, such as Enanpad (Brazilian meeting of research and post-graduate in Business Administration) and Simpoi (Symposium of Logistics and International Operations), both promoted by the Brazilian Association of Research and Post-graduate studies in Business Management. Her research interests include reverse logistics, supplier selection, sustainability in SCM, circular economy and decision analysis. She has several papers and chapters published in both Brazilian and international conferences, journals and books and acts as a referee for numerous conferences and journals, generating more than 270 publications including 94 journal papers, 140 conference papers and 34 book chapters. She has authored one book and edited five.

Preface to ”Food Supply Chain through Ongoing Evolution: Lessons from Continuous Transformations”

Due to the systematization of knowledge on the sequence of activities required for food availability, the following two aspects have emerged: the first is a focus on relationships and the other is the ongoing shaping of these sequences due to continuous transformations, such as the transition to a more sustainable business model, and the development of resilience to face crises, including the crisis we are facing today with the COVID-19 pandemic that has disrupted food production and consumption systems worldwide.

The focus on relationships was quickly established (van der Vorst et al., 1998) with agri-food enterprises developing close relationships in the supply chain (Ziggers and Trienekens, 1999) and seeking more effective forms of coordinating flows both inside and outside the enterprise (Aramyan et al., 2007). Therefore, relationship strategies (e.g., cooperation, coordination and collaboration) in food supply chains can generate positive effects such as better access to markets and resources, improved quality, a reduction in risks, development of resilience, and sustainable gains in social, environmental, and economic dimensions (Santos and Guarnieri, 2020; Thomé et al., 2021; Zaridis, Vlachos and Bourlakis, 2020).

Subsequently, due to these continuous transformations, food supply chains experience constant evolution. Likewise, other elements drive these transformations, including traceability (Kelepouris, Pramatari, and Doukidis, 2007; Galvez, Mejuto, and Simal-Gandara, 2015), food safety and health (Raspor, 2008; Spence and Bourlakis, 2009), local/community development (Marsden, Banks, and Bristow, 2000; Berti and Mulligan, 2016), retail role and power (Newell, Ellegaard, and Esbjerg, 2019; Fulponi, 2006), socioenvironmental practices (Santos and Guarnieri, 2020; Bradley, Parry, and O'Regan, 2020), food waste (Papargyropoulou et al., 2014; Göbel et al. 2015), and, more recently, food supply chain disruptions such as the COVID-19 pandemic (Hobbs, 2020; Singh et al., 2020).

Against this backdrop of the continuous transformation of food supply chains, this book aims to promote and suggest ways by which to understand the mechanisms of change and adaptation that have already occurred in food supply chains across the globe to help manage future transformations.

One important starting point for this effort is recognition of the heterogeneity of food supply chain arrangements (Thomé et al., 2021), in terms of actors, resources, types of relationships, and objectives (Le Velly and Moraine, 2020), which reveal plural forms of food supply chain evolution. Therefore, this book includes chapters explaining food supply chain transformations through different conceptual frameworks, agri-food areas and contexts, as well as multiple levels of analysis.

In this book, paper 1 explores the promotion of win–win investments in Brazil's Agribusiness. Paper 2 presents how family farmers can thrive in commodity markets in long agribusiness supply chains. The Logic of Collective Action for Rural Warehouse Condominiums, which is a new configuration in the agribusiness supply chain, is also addressed in paper 3. The Brazilian Jabuticaba Supply Chain is analyzed through a multi-methodological approach in paper 4. The role of logistics in food-waste reduction for wholesalers and small retailers of fruits and vegetables is also presented in paper 5. Paper 6 discusses the issue of transparency in global agribusiness in the Brazilian soybean supply chain based on companies' accountability. Finally, paper 7 explores the transformation of the food supply chain through technology and presents future research directions.

Karim Marini Thomé , Michael Bourlakis , and Patricia Guarnieri
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Article

Brazil's Agribusiness Economic Miracle: Exploring Food Supply Chain Transformations for Promoting Win–Win Investments

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Abstract: *Background*: For many developing countries, agribusiness has become one of the main economic sectors, with the capacity to mobilize domestic and foreign investments. Despite the potential for development in countries like Brazil, the results of these investments in supply chains have not yet been systematically assessed. *Methods*: This study analyses foreign and domestic investments as an explanation for the recent growth of Brazilian agribusiness and evaluates the implications of different investment arrangements for the future development of the sector in the country. The research was based on a literature review of 12 agribusiness supply chains in Brazil. *Results*: Through a content analysis, the results reveal win–win situations with foreign and domestic investments supporting the streamlining of supply chains, mutually benefiting domestic and international groups and increasing the productivity of the entire sector. However, the results also reveal win–lose cases with chains and segments practically controlled by foreign multinationals in which local groups have practically no share. Finally, there are also cases of lose–win in which groups subsidized by the state are privileged in relation to others, compromising the sector's growth. *Conclusions*: The current liberal business environment results in the need for a new vision of development based on win–win opportunities for domestic and foreign investments created by dynamic sectors such as agribusiness.

Keywords: foreign direct investment (FDI); alternative food supply chain models; conceptualizations of food supply chain transformations; ongoing evolutions and transformations; patents

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1. Introduction

For many low-income countries in South America, Africa, and Asia, the promotion of agribusiness is understood as an option from which to effectively benefit from global investment for the creation of urgently needed job opportunities and income from fees, taxes and exports, and to modernize and strengthen the domestic agricultural sector [1]. Agribusiness is the sum of all operations involved in the manufacture and distribution of farm supplies and production, storage, processing, and distribution of farm commodities [2].

Brazil's has become one of the prime examples of an economic boom promoted by growing investments in agribusiness in recent decades. In 2020, agribusiness as a whole (including supplies, industry, services, and agricultural production) accounted for 26.7% of Brazil's Gross Domestic Product (GDP), while agricultural production alone (primary sector of production in the field) accounted for about 7% of national GDP [3].

There are several reasons for the expansion of agribusiness in Brazil, such as land availability, favourable agrarian and environmental policies for the expansion of the agricultural frontier, agricultural policy's support for the modernization of rural producers through subsidized credit, and political support [4]. However, this favourable environment is not fulfilled without a fundamental aspect: investments. Investments play a fundamental role in explaining the economic miracle achieved by agribusiness in Brazil, and the knowledge of the arrangements that favor ongoing investments is essential to envision the future of the sector.

Particularly since the 1990s, agribusiness has attracted considerable foreign direct investment (FDI), but it has also experienced significant private domestic investment and different public contributions in specific productive segments. The opening of Brazilian trade in the 1990s led to large investments in agribusiness in Brazil, mainly by foreign corporations, but the foreignization did not occur homogeneously in all supply chains or in all production segments. While some supply chains, such as soybean, began to rely on the predominance of foreign groups in their agro industrial sectors [5], other supply chains had more Brazilian investments, including investments in technology [6].

Therefore, understanding the arrangements that favor investments and their implications is fundamental in thinking about the future development of Brazilian agribusiness. The liberal and globalized business environment in which the country is inserted results in the need for a new outlook on development based on opportunities created by dynamic sectors such as agribusiness. A crucial challenge is the consolidation of domestic capital groups along the supply chains, overcoming the growing hegemony of foreign multinationals [7]. The agribusiness segments of the supply chains upstream and downstream of the farms tend to pay better than primary production on farms. This is because the industrial sector offers more opportunities for economies of scale than the agricultural sector, and the chaining and spillover effects are greater than in agriculture [8].

From the identification of the main market arrangements that have led to investments in agribusiness, this study aims to identify the origin of the predominant capital in the main sectors of agribusiness supply chains and analyze its implications for the future of the industry. We intend to analyze how ongoing investments leading to transformations in the agribusiness supply chains can offer strategic possibilities for growth in developing countries. Specifically, we intend to analyze: (1) the participation of foreign, domestic and public investments in the segments of important agribusiness supply chains in Brazil, and (2) the implications of these investments for the future of Brazilian agribusiness due to the possibilities created for domestic participation in win–win segments with better payoffs.

2. Theoretical Framework

Literature on foreign direct investment (FDI) by multinational enterprises has focused on outcomes for the host countries such as spillover effects, technology transfer, firm-level productivity, and performance of subsidiaries [9]. However, empirical evidence has also shown that the effects of FDI are heterogeneous and conditional on factors such as the type of FDI, the economic sector of investment, and the absorptive capacity of the host economy [10]. Productivity spillovers caused by FDI in Brazilian industry vary in terms of size, location, and the technological intensity of firms [11].

Existing studies, however, have only recently started exploring whether and to what degree domestic entrepreneurs can benefit from the economic dynamics promoted by FDI by establishing themselves in the marketplace while competing with multinational foreign enterprises [12]. Theoretically, liberal policies that encourage FDI may lead to: (1) business arrangements where domestic companies successfully compete with foreign companies and benefit from FDI or (2) business sectors controlled by foreign multinationals, with domestic groups having insignificant market shares and poorly benefiting from FDI [13]. In contrast, stronger governmental support may lead not only to significant domestic market shares but also to privileges and poor development.

Investment takes place when there is a direct interest of the parties concerned in a specific segment or economic sector [10]. Private direct investments are made by companies responding to market dynamics [9]. Public (governmental) investments are made through specific public programs and reforms [14]. In Brazil, specifically since the 1990s, the neoliberal economic perspective has been promoted through relaxed economic regulation and privatization policies [14]. With economic liberalization, the entry of international capital into the country boosted agribusiness and created a more competitive environment for national groups [15]. However, a more sophisticated industrial base is a sine qua non condition for an emerging economy to converge from those already developed [16]. Therefore, it is necessary to create opportunities for domestic groups to increase their share in industrial sectors based on long-term policies, including industrial and technological policies [16].

The current situation of the liberal and globalized business environment in which the country operates results in the need for a clear assessment of the opportunities created by dynamic economic sectors such as agribusiness for domestic groups to thrive. A crucial challenge is the consolidation of companies with domestic capital throughout the supply chain of agribusiness in developing countries [17]. This challenge, certainly, ought to consider identifying the business arrangements most capable of absorbing the benefits of FDI, especially in terms of productivity, given the asymmetry in the levels of absorption of these benefits, as pointed out [11–18].

The role of investments can be involved in win–win, win–lose, and lose–lose arrangements [13–19]. Win–win outcomes occur when both sides benefit from the scenario; otherwise, win–lose situations result when only one side perceives the outcome as positive, and lose–lose means that all parties end up being worse off [19].

Building on this background, a key academic question that needs to be addressed is to what degree domestic entrepreneurs can establish themselves in the business and benefit from FDI which promotes dynamic economic sectors, such as is the case for agribusiness in Brazil in recent decades.

3. Methodology

In Brazil, measurements of the importance of agricultural production are made in Gross Value of Production, in accordance with the Brazilian Institute of Geography and Statistics (IBGE), and the relevance of agribusiness as a whole has been calculated in terms of GDP, as used by Cepea [3]. Finally, the relevance to the trade balance is estimated in currency. None of these measures, however, enables us to distinguish the extent of the participation of domestic groups in relation to foreign ones. Therefore, this study proposes the construction of an approach that considers participation in the market and the origin of the capital of the different companies acting in each segment.

To achieve the proposed objectives, this study was based on an integrative review [20,21] of empirical studies and on documental research carried out in institutional publications of sectoral organizations and companies. The integrative review of empirical studies followed the six steps proposed by Ercole et al. [21]. In the first stage, the research theme was delimited (participation of domestic capital in the agribusiness supply chains in Brazil). In the second stage, the criteria for inclusion and exclusion of studies were established, considering only empirical studies (articles and books) available in the Capes, Scielo and Google Academic databases. We selected 12 empirical articles published in scientific journals and 8 scientific studies published as book chapters.

In the third stage, the information to be extracted was defined at that related to the following keywords: "Brazilian participation", "Brazilian capital", "agribusiness", "production chain", in an interleaved manner and with the use of the Boolean operators "and" and "or", in Portuguese and English, in the title, abstract and keywords. At this stage, we prioritized studies that described aspects related to the following categories of analysis: (1) the main segments of the production chains in Brazil, (2) the activities developed by these segments, (3) the main companies operating in each productive segment (name, nationality and shareholding control), and (4) the market share of companies in the segments of the supply chains.

In order to standardize this information in all the analyzed production chains, it was necessary to carry out document research on institutional materials from sectoral associations and the companies themselves. To estimate the participation (market share) of the companies operating in each segment, first we quantified the total sales in the country for each input in each segment of the four supply chains (e.g., 5580 soybean harvesters sold in Brazil in 2019), according to the assumptions established by Medina and Tomé [22]. We then identified the major international and domestic companies operating in each segment (e.g., CNH, John Deere, and AGCO in the case of soybean harvesters), and their total sales (e.g., 2903 soybean harvesters by CNH, 2269 by John Deere, and 408 by AGCO) [22]. To estimating the participation of domestic groups in relation to multinationals, we surveyed the shareholding composition of the companies as reported by Medina and Tomé [22]. To estimate the total market share of domestic groups in each segment of the production chain, the market shares of all companies with Brazilian capital were summed. The domestic participation in the production chain resulted from the weighted sum of the participation of business groups with Brazilian capital in each of the seven segments analysed (from seeds to marketing, see Figure 1).

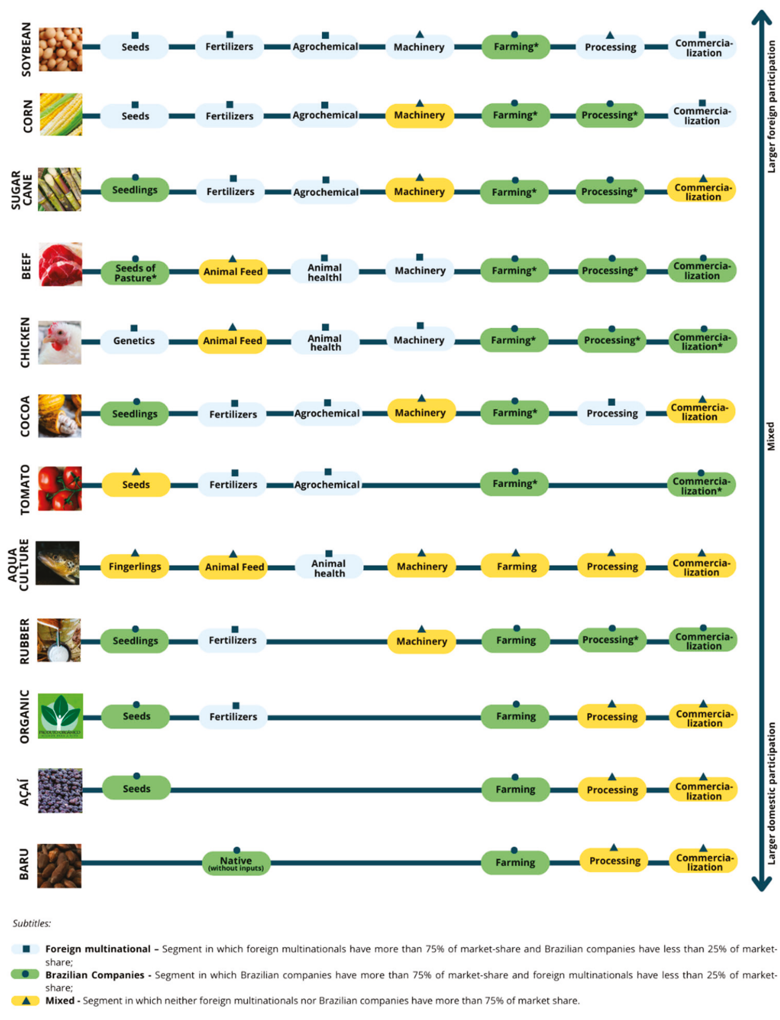

Figure 1. Participation of Brazilian and foreign economic groups in key segments of the supply chains analysed.

In the fourth stage, the aspects mentioned above were described for the 12 production chains studied. In the fifth stage, the results were interpreted, based on a discussion of the segments of the supply chains studied in which foreign capital predominates or domestic capital predominates (partly with state support), and the segments in which neither domestic nor international capital dominates. The sixth and final stage discusses the implications/understandings of the investment arrangements identified in the various segments of the supply chains.

Stages four, five, and six of the integrative review were conducted through the content analysis proposed by Bardin [23], being carried out in three phases: pre-analysis, material exploration, and treatment of the results [23]. In the pre-analysis, we carried out a preliminary review of the selected documents. In the second phase, we observed the themes that were repeated in the studies and chose the initial categories, i.e., the coding, classification, and categorization units [24]. Based on the content analysis, it was possible to group the initial categories and understand the recent growth of Brazilian agribusiness through three thematic categories: I. preponderance of foreign investments; II. the preponderance of investments made by domestic groups; III. mixed foreign and domestic investments without a clear preponderance. The third phase of the content analysis consisted of the treatment of the results through the inference and interpretation of the information collected in the integrative review.

4. Results

The supply chains analysed have different productive segments with distinct investment arrangements. Comparing the chains, trends were identified as follows: 1. There are cases of preponderance of foreign investments, as in the soybean and corn supply chains as a whole, and in segments associated with cutting edge technologies such as patented seeds, pesticides and animal health; 2. There are cases of preponderance of investments made by domestic groups, as in segments such as farming production and non-patented seeds; and 3. There are cases of segments with foreign and domestic investments without clear preponderance, which were called mixed segments (Figure 1). Throughout this results section, all the supply chains and segments evaluated in this study are presented, following the summary in Figure 1.

The set of chains presented has a total of 73 segments analysed. Of these segments, 25 (34%) are controlled mainly by foreign groups, 27 (37%) by domestic groups, and 21 (29%) are considered mixed without preponderant participation of domestic or foreign groups. Of the segments controlled by domestic groups, 12 (44.44%) are supported by direct public policies.

4.1. Soybean Supply Chain

The Brazilian market for transgenic seeds of soybean is firmly dominated by multinationals; specifically, the German company Bayer, with a market share of 90% [25]. Two-thirds of the profit from the final price of seeds remain in the hands of the multinational licensor, while the remaining 35% goes to seed producers, as they pay royalties for the use of patented transgenics [26]. In the segment of seed production, Brazilian companies hold 25% of the market share [27]. Thus, in the segment of seed production, domestic capital would be equivalent to only 8.7% (35% of the profits from the 25% market share) [27].

In the fertilizer segment, two types of companies operate, those that produce and those that use raw materials to manufacture specific fertilizer products. The multinational MOSAIC controls the raw material sector and the overall share of domestic groups has dropped to less than 9%. Concerning fertilizer manufacturers, the Brazilian market is dominated by the multinationals YARA and MOSAIC. Brazilian groups hold less than a third of the market, particularly the FERTIPAR Group and HERINGER. Brazilian participation in the fertilizer market can be estimated at less than 20% [27].

The agrochemical segment is divided into products with patents and generic products authorized after patent exclusivity periods. Product patents are fully controlled by multinational groups. ChemChina (who bought SYNGENTA), BAYER, and BASF hold a significant market share. Generic products are very largely under the control of multinational companies, but some industries with domestic capital such as NORTOX and Ourofino Agrociência still have a stake. Overall, companies with national capital made less than 6% of the agrochemicals traded in Brazil [28].

The soybean-farming market for heavy machinery is controlled by a worldwide oligopoly characterized by mergers and acquisitions led by the following international groups: John Deere, CNH (holder of the brands Case and New Holland), and AGCO (holder of the brands Massey Ferguson and Valtra). The three groups combined control 99.6% of tractor sales and 100% of combine harvesters' sales in Brazil [29]. Agrale produces small-sized tractors with limited application in soybean farming and is the only relevant domestic company in this industry. There is a greater, but undefined, market share of domestic companies for agricultural implements such as ploughs, scarifiers, limestone spreaders, and cultivators.

Large multinational trading companies such as ADM, Bunge, Cargill, and Dreyfus (known as the ABCD Group) dominate the soybean processing and trading segments. Recently, China has massively invested in the segment of processing and trading, not only in Brazil but also in many other countries. In Brazil, the China National Cereals, Oils, and Foodstuffs Corporation (COFCO) purchased the Brazilian Noble Agri (trade). In total, domestic groups, including companies and farmers' cooperatives (e.g., Coamo and Comigo), control less than a fifth of the processing and trade of the soy produced in Brazil.

4.2. Corn Supply Chain

Corn is the basis for different supply chains such as pork, chicken, eggs and ethanol [30]. Corn production directly interferes with the chains involving products deriving from poultry, pork, milk and beef cattle, whereas the poultry and pork sector is highly dependent on this product [31].

The corn supply chain consists of the input sectors such as suppliers of pesticides, fertilizers, seeds, machinery and equipment; production itself (family or business producers); storage (cooperatives and public or private warehouses); processing (primary, covering the animal feed industry, the production of starch, corn flour and corn flakes; and secondary, including other end products, cereals, and cake mixes); distribution (for wholesale and retail, external and internal); consumption (from the farm to the chemical industry); institutional environment (legislation and government marketing mechanisms) and the organizational environment (bodies linked to technical assistance, credit and research) [32].

The Brazilian market is mostly dominated by multinational companies since it is one of the world leaders in the production of corn [33]. The Norwegian company Yara is the main owner of the occupation percentages within the fertilizer segment, and has a 4% Brazilian share [33]. The seed and agrochemical conglomerate is dominated by an oligopoly of the large companies Bayer, Syngenta and Corteva, justified by transgenic events that guarantee resistance to herbicides, insects or both [33].

As for machinery and implements, the Deere & Co group is responsible for more than 50% of the sector's revenues, with the Brazilian company Stara standing out, although with less than 1% of the market [33]. Finally, according to Corcioli et al. [33], marketing is the segment that moves the most resources within the corn production chain, with the highest revenues among the five segments, especially in the Cargill company, leader of the segment, and the Brazilian company Amaggi, which in 2019 had revenues of US$ 5 billion. Marketing is of paramount importance for producers; after all, it will lead to their financial results. Although part of the production is consumed in Brazil, some of it is exported. Thus, these companies have great relevance because they have the opportunity and the right conditions for large-scale acquisition to foster external demand [33].

There are two processes that give rise to industrialized corn products: dry milling (flours, snacks and breakfast cereals) and wet milling (oils, syrups and beverages) [34]. Approximately 70% of the corn produced in the world is destined for animal consumption [35].

The companies with the largest number of establishments authorized to manufacture feed in Brazil are: Seara Alimentos Ltd.a. (17.4% market share), BRF S.A. (market share of 12.5%), and Cargill Alimentos Ltd.a (market share of 8.9%) [33]. Regarding the participation of cooperatives in the production of animal feed, at least 300 sites were identified, especially the Aurora Alimentos Cooperative, with seven sites. Alfa Agro-industrial Cooperative and Catarinense Rural Agricultural Cooperative, both with six sites, C. Vale—Agro-industrial Cooperative, with five sites and Coamo Agro-industrial Cooperative, Copacol—Consolata Agro-industrial Cooperative and Lar Agro-industrial Cooperative, both with four sites [36].

4.3. Sugarcane Supply Chain

Contrary to soy, the breeding of sugarcane varieties is primarily a domestic domain, which largely reflects a significant promotion by public investment. Two-thirds of the sugarcane varieties cultivated in Brazil stem from the Inter-University Network for the Development of the Sugarcane Sector (RIDESA), a combination of ten universities. The other leading varieties are CTC, SP, IAC, and CV, representing 14%, 13%, 2%, 2%, and 4% of the planted area in Brazil, respectively [37].

The fertilizers and agrochemical market for sugarcane are similar to those for corn and soybean. Agricultural machinery for sugarcane farming includes harvesters, planters, sprayers, and trans-shipment trucks. The market for sugarcane harvesters is controlled by CNH and John Deere, which have by far the largest market shares [29]. In the case of planters, there is important participation by Brazilian groups such as DMB Máquinas e Implementos Agrícolas Ltd.a, TMA Máquinas (from the Tracan Group), and Sollus Agrícola. The Brazilian company Jacto, but also the French company Berthoud and multinationals AGCO (Valtra), CNH (Case), and John Deere, also operate and lead in the market for sprayers and other implements. Moreover, Brazilian groups mainly deliver sugarcane crushing industrial equipment. However, most of these groups act based on partnerships or joint ventures with multinational groups for the use, development, or import of technologies. Examples are Dedini S.A. Indústrias de Base, a domestic company that established a partnership with the Indian PRAJ industries in 2019, and Zanini Renk, a joint venture between the Brazilian Zanini and the German Renk AG for technology transfer from Germany to Brazil.

Regarding sugarcane mills, the situation is quite different. More than two-thirds of sugarcane processing is carried out in industrial plants held by Brazilian groups. In Brazil, there are 234 alcohol and sugar mills and another 178 alcohol distilleries. These 412 agro-industrial units process 643 million tons of sugarcane per year [38]. The Brazilian group Copersucar S.A. alone processes 85 million tons of sugar cane in 34 plants belonging to 20 different economic groups [39]. The Brazilian São Martinho Group leads the ranking for profitability [40]. Only recently, the segment has also attracted multinational groups. For example, the second-largest milling group is Raízen, a fifty–fifty joint venture between the Brazilian company Cosan S.A. and the multinational Royal Dutch Shell. BP British Petroleum formed a joint venture with Bunge within the newly created BP Bunge Bioenergia. The Atvos Agroindustrial group is moving from Brazilian controllers to American. Tereos Açúcar & Energia Brasil is part of the Tereos Internacional Group, a global French company. The Indian group Shree Renuka Sugars Ltd. Has also invested in the segment and today can process 13.6 million tons per year in Brazil.

Four large multinational groups control the Brazilian sugar market. However, Brazilian companies have created ethanol and sugar trading groups to increase their bargaining power vis-à-vis distributors [41]. Copersucar, for example, sells ethanol directly or through eco-energy, a trading company controlled by Copersucar. Sugar is sold through Alvean, a fifty–fifty joint venture formed by Copersucar and Cargill. The leader in the ethanol segment is the multinational Raízen, with 16.5 billion liters sold annually. Overall, domestic groups share 42.9% of the trade of sugar (23.1%) and ethanol (62.6%), totaling approximately 55.2% for the entire sugar segment.

4.4. Beef Supply Chain

The Brazilian market of pasture seeds is fragmented, but also sees a large participation from domestic groups. This reveals the lack of patented leading technology, which constitutes a barrier for market entry. Matsuda, a privately held Brazilian company, is a large player in this segment. The cultivars released by the Brazilian Agricultural Research Corporation Embrapa, mostly selected based on natural variability, account for more than 70% of the Brazilian forage seed market [42]. Recently, some multinationals have also started entering the market, for example, Barenbrug do Brasil, a company of the Royal Barenbrug Group based in the Netherlands, which started operating in Brazil in 2012.

The largest companies in the cattle feed segment are the multinationals Cargill and DSM. Together, they produce 15 million tons of feed per year, equivalent to 20% of the Brazilian market [43]. However, because of the high transport costs for heavy goods, the Brazilian feed market as a whole is in the hands of several small and large regional Brazilian companies. Among them, PREMIX stands out with a market share of 10%. Overall, the market share of domestic groups in the feed segment is estimated at 70.7% [42].

The animal health segment in Brazil is largely controlled by the four multinational groups: MSD, Zoetis, Boehringer Ingelheim, and Elanco, since they own the patents for all relevant state-of-the-art drugs [44]. MSD Saúde Animal is the veterinary arm of the American pharmaceutical Merck that bought the Brazilian veterinary industry Vallée in 2017, which was one of the leaders in the segment in the country. Zoetis, the actual leader in the global animal health market, was created after Pfizer Inc. decided to transform its animal health unit into an independent company. The largest group with domestic participation is the specialist in generic products Ourofino Saúde Animal, a publicly-traded company. Still, the original Brazilian shareholders hold 56.3% of the company. Another 16.9% is in the hands of the General Atlantic, a private equity company investing in growing companies. Other domestic companies are UCBVET, Calbos, Agener União, Real H, and JA.

The principal equipment used in beef cattle farming consists of containment trunks and weighing scales. A large number of domestic companies are active in this market segment because simple technologies require low initial investments and limited expertise [42]. Some companies such as Açôres have recently started investing in research to improve product performance and to search for alliances with multinational companies.

Officially, 67,058 cattle are slaughtered per day in Brazil [45]. The slaughterhouse segment is concentrated in three large public Brazilian companies: JBS, Marfrig, and Minerva [42]. JBS is a multinational controlled by the Brazilian company J & F Investimentos S.A. and has a broad range of shareholders: J & F Investimentos S.A. and Formosa with 39.8% share; a smaller treasury share (2.3%); BNDESPar, the investment branch of the Brazilian National Development Bank—BNDES (which also invested in Marfrig) with a 21.3% share; and other minor shareholders such as Brazilian public bank Caixa Econômica Federal (CEF) with 4.9% of the shares (JBS, 2020). JBS is the leading company in Brazil with an installed capacity to slaughter 34,200 heads of cattle per day, which corresponds to 51.0% of the Brazilian market. Likewise, JBS, Marfrig, and Minerva also went public, and domestic shareholding was estimated at 85% and 46.8%, respectively [46]. Despite market concentration in these three companies, there are another 1334 slaughterhouses registered by the federal inspection service [45].

4.5. Chicken Supply Chain

The poultry genetics segment in Brazil is controlled by two foreign multinationals: Aviagen and Cobb. The German group Erich Wesjohann (EW) controls Aviagen, and Cobb-Vantress, the poultry genetics arm of American Tyson Foods, is a world leader in the supply of poultry for broilers and in technical expertise in the poultry sector. Headquartered in Arkansas, United States, Cobb-Vantress has been present in Brazil for 22 years. By 2022, the company wants to reach the capacity to produce 42 million matrices, a number that includes the gaucho partner Agrogen [47]. In Brazil, only the two leaders in chicken meat (JBS/Seara and BRF) have the scale to buy poultry; the other industries buy matrices.

Considering the control of the multinationals, the participation of Brazilian groups was estimated at 1% in this market segment.

In the chicken feed segment, only animal nutrition companies market a portion of the feed, which corresponds to premixes and additives. The largest companies in the premixes and additives segment operating in Brazil are the multinationals Cargill and DSM. There are also Brazilian companies with a relevant share in the national animal nutrition market. The high cost of transportation, due to the weight of the products, ends up favoring regional groups. These factors, related to physical proximity and relationships, help explain why Brazilian groups hold 60.7% of the market [48].

Four multinational pharmaceutical groups control the animal health segment in Brazil: MSD, Zoetis, Boehringer Ingelheim and Elanco [49]. This control is largely related to the development and patenting of the latest technology drugs. Despite multinational control, domestic groups have an important share of the animal health market, particularly in the generic drug segment. Among the groups with domestic capital with significant market share, Ourofino and UCBVET stand out. The domestic share in the animal health segment in Brazil was estimated at 15.3% of the total.

The poultry chain has great demand for equipment. There are several categories of equipment, and the ten main categories are: slaughter, breeding, packaging, feed mill, freezing, hatchery, meat processing industrialization, laboratories, transportation and clothing. In this article, we considered only the breeding equipment that is acquired directly by the chicken producers from the commercial representatives of the manufacturing companies. This segment is mainly controlled by large multinational corporations, although there are competitive Brazilian companies with an estimated market share of 15% of the total market [48].

In the meatpacking segment, Brazilian multinationals JBS and BRF that control almost half of the market currently leads chicken meat production in Brazil. Other domestic groups with a tradition in Brazil control the rest of the market. In recent years, JBS has achieved leadership of the Brazilian broiler market by incorporating Céu Azul, Big Frango and Tyson. JBS is a multinational public listed company controlled by the Brazilian J & F Investimentos S.A. The participation of domestic groups in this segment of the chicken supply chain was estimated at 82.8%. This estimate was made considering only the Brazilian participation in the companies JBS and BRF (75% and 53.8% respectively) and the fact that all other companies in the segment are Brazilian [48].

4.6. Cocoa Supply Chain

Most of the 4.6 million tons of cocoa processed in 2020 occurred in Europe (36%), Oceania and Asia (24%), Africa (22%) and the Americas (19%) [50]. The largest continent (Africa) as a global producer of cocoa beans processed only one million tons, exporting the surplus, mainly to Europe, the continent that has the highest per capita consumption of chocolate in the world. In the Americas, the countries with the largest share in global cocoa processing are the United States (8%) and Brazil (5%) [51].

In Brazil, three multinational companies predominantly dominate the processing segment: Cargill, of American origin; Callebaut, from the Belgian group Barry-Callebaut; and Olam, of Nigerian origin, now controlled by Temasek Holdings (a Singaporean state company) and the Mitsubishi Corporation [52]. Together these companies account for 97% of national cocoa bean processing [53]. This concentration constitutes an oligopsony (i.e., few buyers) market structure [54]. Although most of the outputs of the cocoa processing link are directed to the domestic market and the smallest part to other countries, the trade balance with the latter is positive, unlike the situation in the processing link of other rural producers [54].

The insertion of Brazilian cocoa in the global market is basically restricted to the agricultural segment, which has structural shortcomings that compromise the competitiveness of the cocoa supply chain, and is predominantly represented by family farming, a segment that, although it plays a key role in ensuring food security in Brazil, traditionally faces unfavorable competitive conditions compared to those for exporting agribusinesses [54]. The competitiveness of cocoa requires more favourable conditions for effective and sufficient access to resources capable of modifying the production structure of rural properties, technologies and technical support in order to ensure increased productivity [54].

On the other hand, the insertion in possibly more profitable arrangements, such as fine cocoa or vertical integration for the production of chocolates, also presents its own challenges, such as technological and knowledge barriers and increased transaction costs [54]. These barriers can, however, be mitigated with possible collective strategies aimed at producers, with the support of other organizations directly and indirectly interested in cocoa [54].

Whether via strategies to increase agricultural production or via insertion in potentially more profitable arrangements or even by combining both possibilities, these options do not concern only rural producers, but also the multiple organizations and actors directly or indirectly interested in the sector [54]. These strategies should be seen as a means of promoting the competitiveness of Brazilian cocoa in a context that favors social inclusion and the mitigation of its environmental impacts [54].

4.7. Tomato Supply Chain

In the tomato seed segment in Brazil, the companies with the largest market share are, respectively, Agristar, Syngenta AG, Monsoy, Blue Seeds and Sakata Seed [55]. Agristar, the market leader, is headquartered in the city of Santo Antônio de Posse, São Paulo, and has four experimental stations and a research and improvement unit in the states of São Paulo, Minas Gerais, Santa Catarina and Rio Grande do Norte. Syngenta AG, based in Basel (Switzerland), has been operating for 15 years with research and development activities focused on crop protection and seed production [56]. Monsoy, the current global vegetable seed branch of the German company Basf, operates in Brazil under the brand Nunhems. Blue Seeds, occupying the fourth position in the domestic market, is a national company based in Holambra/SP, with more than 20 years in the seed market aimed at the fruit and vegetable chain, covering the various soil and climate conditions in the country [56]. Sakata Seed, a Japanese company that produces and sells vegetable and flower seeds on the global market, entered Brazil in 1994 through the acquisition of Agroflora. It currently has more than 250 vegetable cultivars and 500 flower cultivars [56].

The agrochemicals segment in Brazil raised in 2019 the equivalent of US $13.7 billion [56]. It is a concentrated market dominated by the companies Bayer CropScience, Syngenta, BASF, Corteva, FMC and UPL. Together, these companies control about 90% of the market [57].

The weakest and least coordinated link in the sector is in the production segment itself (inside the gate or on the farms) [56]. In the tomato chain, producers act in a more individualized and disarticulated way, sending their production to the State Supply Centres (wholesalers), selling directly to the retail sector or passing it on to middlemen, thus being at the mercy of unexpected changes in sale prices [56]. It is worth noting that, unlike industrial tomatoes, which experience a high degree of processing controlled by foreign multinationals, fresh tomatoes are marketed mainly by local agents [56].

It is worth mentioning that the production of tomatoes for fresh consumption mostly serves the domestic market, with the country participating with only 0.1% by weight of fresh or chilled tomato exports in the year 2017 [56]. The destination of the Brazilian product was the Mercosur countries, especially Argentina, while the main exporters were the states of Minas Gerais, São Paulo and Santa Catarina [58].

In recent years, in the tomato chain, the production of gourmet products and the creation of a brand associated with the product and its attributes have been a growing trend [56]. In this regard, the Trebeschi companies and the Mallmann group stand out on the national scene, maintaining their own production in protected fields and environments, for the most diverse gastronomic uses, with traditional and gourmet products that cater to different audiences [56].

4.8. Aquaculture Supply Chain

The world fish market is dominated by the following companies: Aquamaof (Revivim-Israel), Homey Group International (Shanghai-China), SalmonchilE (Santiago-Chile), Camanchaca (Santiago-Chile), Multiexport Foods (Puerto Montt-Chile), Cooke (Blacks Harbour-Canada), Rainforest (San Jose-Costa Rica), Regal Springs (Medan-Indonesia), Blue Gulf Seafoods (Shandong-China), Hainan Qinfu Industrial (Hainan-China), Expalsa (Guayas-Ecuador), Songa (Guayaquil-Ecuador) and Omarsa (Durán-Ecuador) [59]. These multinational companies, with a high degree of organization and production, can positively affect the Brazilian market, improving national productivity through new production technologies and genetic strains, but also negatively, taking international market shares from Brazilian companies or placing products with much higher level of competitiveness than Brazilian companies can achieve [59].

Data from IBGE [60] referring to the year 2019 show that the value of the production of young forms of fish is distributed in fish fry (65.97%), shrimp larvae and post-larvae (33.68%) and mollusk seeds (0.35%). The first are mainly composed of Nile tilapia fingerlings, whose main producers are the Aquagenetics Group (Aquabel and Aquamérica). Aquatec and Aquasul produce shrimp larvae and post-larvae, while shellfish seeds are distributed, almost exclusively, by UFSC [59].

In the feed manufacturing segment, the main players are Neovia, Guabi, Supra, Raguife and Comigo, for consumer fish, and Alcon, Nutricon, Maramar, Poytara, for ornamental fish (Rodrigues et al., 2021). With the exception of Raguife, Guabi and Comigo, which are Brazilian, the others have foreign capital participation [59].

For the production equipment segment, the domain is dominated by national industries, such as Alfakit, AcquaVita, Cardinal, Trevisan and Beraqua, regarding production equipment for broiler fish, and international companies, such as YSI and Horiba, regarding production equipment for ornamental fish [59]. Brazilian companies suffer strong competition from imported equipment with lower prices [59].

In the production segment (fattening), fish production in Brazil represents 88.39%, and shrimp and mollusk production 9.07% and 2.54%, respectively [59]. In terms of value (R$) of production, fish represent 73.26%, shrimp 25.14%, mollusks 1.47% and the other aquatic organisms only 0.13%. This primary production segment of the aquaculture supply chain represents in Brazil about 5 billion reais per year [59]. Although fish farming (pisciculture) in Brazil represents in volume the largest share of fish production, the average price per kilogram (kg) of shrimp is generally three times higher than the average kg values of the other two groups (fish and shellfish) [59]. The largest producers (fattening) of fish on the national scene are the foreign multinationals Ambar Amaral and Geneseas, and the Brazilian Copacol, C Vale and Tilabras (for Nilvo tilapia), Zaltana (for round fish) and NR Trutas (for trout). In shrimp production, Potyporã and Camanor stand out [59].

In the animal health segment, the main performers are Bayer and MSD, for international capital, and Aquivet, for national capital [59]. Danubio Piscicultura and Moana Aquacultura marketing the hormones used in hormone induction, and hormones for sexual reversion are imported from the foreign company FAV and distributed by the Brazilian company Nexco [59].

The processing and transformation segment of the aquaculture chain is a skilled industry with several operations, such as reception, gutting, washing, processing, packaging, freezing, storage, shipping and transport [59]. The main industrial plants are in the states of Paraná (Copacol, C. Vale and Brasilian Tilapia), São Paulo (Brasilian Fish, Mcassab), Mato Grosso do Sul (Geneseas), Mato Grosso (Delicious Fish), Minas Gerais (Coopeixe, Tilapia da Serra, NR Trout), Rondônia (Zaltana) and Goiás (Lake’s Fish). The major companies use large imported processing equipment, and there is strong interest from foreign companies in investing in the segment and aiming at exporting to other countries [59].

4.9. Rubber Supply Chain

The rubber tree, which is native to the states of Amazonas, Acre, Pará, Roraima and Rondônia, began to be cultivated for economic purposes during the 1950s in several other Brazilian states [61]. Currently, extractivism still predominates in the northern region and cultivation (heveiculture) in the other states [61]. Despite being a country considered uncompetitive compared to the world's largest rubber producer (Thailand: 4.8 million tons), Brazil exported about 600 tons of rubber in 2018 to Latin American countries (FAO, 2021). Nevertheless, Brazil is a major importer of this product, as it imports over 60% of its consumption from countries such as Indonesia and Thailand [62]. This high level of importation makes the country often vulnerable to the international market, since the number of heveiculturers is still small, and the production system is based essentially on family farming, whose use of technology is low [63].

After being removed from the field, rubber is sent to 33 processing plants [62], most of which belong to the French company Michelin and the Brazilian companies Bráslatex, Hevea Tec, Colitex, QR Borrachas Quirino, Globorr, Noroeste Borracha, São Manuel, Agroindustrial ltuberá, Ask and SK [63]. Currently these plants are experiencing idle capacity and some are even economically unviable, due to the low latex supply, high demand and strong pressure from the automotive industry [64].

The main demanding party for processed rubber is the tire industry, as only 8% of this raw material is destined for other industries [65]. The main consumer companies for beneficiated rubber are Asian, European and North American tire manufacturers [63]. Goodyear, Michelin, Pirelli, Prometeon, Bridgestone, Continental and Sumitomo account for about 78% of the Market Share [63].

4.10. Organic Supply Chain

One of the major challenges of the organic supply chain in Brazil is the low availability of seeds [66]. The cultivation of organics in the national territory is dominated by conventional seeds [67], with some presence of imported seeds [66]. The pioneer companies of organic seeds in Brazil are Bionatur (RS), Isla (RS), Horticeres (MG) and Agristar, which launched its Naturalis line on the market, with seeds of 12 different vegetables [66]. In addition to these Brazilian companies, other major foreign players have entered the segment attracted by growth prospects, such as Koppert Biological Systems, Sumitomo Chemical, Bayer, Basf, Corteva and Syngenta [66].

The processing segment can be divided into two levels: primary processing and secondary processing [68]. Most of the companies that operate at the first level provide supplies and technical assistance—reproducing in part the integration process of other agro-food supply chains [66]—have their own brands, manage stands in supermarkets, and make sales directly to consumers and to secondary processing industries [66]. This group includes cooperatives or producer associations and companies with national capital [66]. Second-level companies generally use raw material from their own production [66], but also capture raw material from producers or primary processors [66]. This level includes several industries, ranging from traditional food industries, which use conventional production lines to process organics, to small cottage industries with specific production lines [69].

A movement of mergers and acquisitions has been observed in the organic product processing segment, as domestic industries have been bought by large corporations. Unilever acquired Mãe Terra in 2017, with the objectives of growing in the healthy products market in Brazil and internationalizing the brand [70]. The Paraná's Jasmine was bought by the French Nutrition et Sante in 2014, a company controlled by the Japanese Otsuka Nutraceuticals, a leader in the category of healthy, organic and functional products in Europe [66]. Thus, with the acquisition of Jasmine, Nutrition et Sante began to compete for leadership in the domestic market with the companies Nutrimental, Vital and Kobber [71].

4.11. Açaí Supply Chain

Four distinct systems predominate in the açaí supply chain: extractivism, management in floodplain areas, cultivation with irrigation, and cultivation without irrigation on the dry land areas [72]. Due to the high initial investment required, irrigated açaizeiro is recommended for medium and large-scale farmers. However, this does not rule out irrigated plantations by small farmers for those who can improvise irrigation systems with lower costs, taking advantage of watercourses or dams [73]. Pulp production, on the other hand, can be divided into two systems: artisanal (carried out by "beaters"), which supplies regional consumption, and large-scale (carried out by industrial processors) to supply the national market, especially the southeastern region, and the international market [74]. In the industrial processing segment (large-scale) the main companies are the American Sambazon and the Brazilian Cooperativa Agrícola Mista de Tome-Açu (CAMTA), Petruz Açaí, which exports to 35 countries in Europe, America, Asia and Africa, Bony Açaí, Palamaz, focused on the domestic market, Açaí Amazonas, focused on exports and the domestic market. These companies are able to meet, at national level, the specifications of distributors, usually limited to the content of total solids and sometimes pasteurization, and the international market, more rigorous in terms of food safety, sanitary conditions, pasteurization and complementary analysis (anthocyanin content, for example) and the laws of the destination countries. In addition to its use as food, açaí can be used in the cosmetics industry [75].

The flow of commercialization of açaí occurs on three levels. The first is defined by commercial transactions, between producers and buyers of the fruit at the production site, carried out under a perfect competition regime, except when the production is negotiated with agro-industries, in which a few buyers acquire a large part of the production of a given site. The second level is defined by commercial transactions between wholesalers, who gather a large volume of fruit, and local buyers. At this level, a small number of wholesalers set the resale price of the product for a large number of buyers [72]. The third level is defined by commercial transactions of açaí wine and derivatives in the retail market, where açaí greengrocers and churners operate under perfect competition, distributed in all neighborhoods of urban centres. At this level, the other products (blends, mix, pulp, ice cream, etc.) are also commercialized in supermarkets and special places, which have the power to set the selling price for consumers [72]. The domestication of the açaí is still in its initial steps and management practices still need further development in order to address environmental challenges and long-term maintenance [76].

4.12. Baru Supply Chain

The baru is a fruit native to the Brazilian Cerrado with production coming from nature, from collection by agro-extractivists on their properties, in common areas of agrarian reform settlements, and on large farms, with the authorization of the owners and upon payment of a charge on the amount collected [77]. The fruit is collected manually and only those fallen on the ground can be gathered [77]. The roasted chestnut is the most consumed and well-known product from the baru. However, there is research on the use of baru's pulp and peel. Rocha and Cardoso Santiago [78] developed wholegrain bread with pulp flour, which increased the nutrients in processed food. Other research has demonstrated the potential of the bark to be transformed into charcoal [79].

Stakeholders taking part in the baru production chain are: (i) agro-extractivists who collect the fruits and those who benefit from it, (ii) cooperatives, (iii) a network of intermediaries (companies, middlemen), and (iv) final consumer [77]. Baru has the specific dynamics of a native fruit, with all its production still coming from nature along with part of its artisanal processing [80]. Processing is currently done in two ways: artisanal and industrial. The former is performed by the agro-extractivists themselves, and the latter by the cooperative Copabase, with Brazilian capital, and by Barukas, a foreign company. The first uses only the nut of the fruit, roasting it and selling it on the national market to large industries, wholesalers and final consumers, at their own commercial points at fairs and events. The second buys the whole fruit and exports it packaged in 50 kg bags [77], processes the roasting of the nut and extracts the fruit pulp.

In Brazil, Barukas offers the roasted nut in 90 g packages and the mix of the nut and the dehydrated baru pulp, also in 90 g packages [77]. In the United States, its portfolio of baru products consists of baru nuts with sea salt in 340 g packages, roasted baru nuts in 340 g packages, baru nuts with dark chocolate coating in 113 g packages, the mix of nuts and dehydrated baru pulp in 340 g packages, and baru butter in 227 g bottles [77].

5. Discussion

The comparative analysis of the different agribusiness supply chains based in Brazil makes it possible to explain the investments made in the sector and assess their implications for the future of the country's development. Based on the content analysis, it was possible to assess the recent growth of Brazilian agribusiness in three market arrangements: (I) preponderance of foreign investments; (II) preponderance of investments made by domestic groups; and (III) mixed foreign and domestic investments without a clear preponderance. On the one hand, there are supply chains and specific segments with greater participation and control by foreign multinational capital. On the other hand, there are specific segments with greater participation of domestic groups, in some cases with greater support from incentive policies. Finally, there are mixed segments in which domestic and foreign groups compete without consolidated control.

5.1. The Foreign Dominance of Part of Brazilian Agribusiness

Preponderance of foreign investments was observed both in supply chains as a whole and in specific segments of most of the chains studied. Illustrative examples include:

- Soybean and corn supply chains
- Transgenic seed segments with patents, high-tech machinery and state-of-the-art chemistry (not generics) including fertilizers, agrochemicals and animal health.

In most cases, these tend to be high technology sectors that require large investments and are often protected by patents. In these segments, the participation of domestic groups is smaller and often restricted to generic products. From this specific perspective, it can be said that patent protection in the country strengthened foreign control in some segments, such as transgenic seeds. Surprisingly, even in supply chains of organic products, there are segments with strong participation of foreign capital, as is the case with fertilizers.

In most cases, the segments that have attracted massive foreign investment are those in which domestic groups have failed to prosper. In the context of the country's agro-industrial development, these are segments that can be considered win–lose, given the advantages of foreign groups, which obtain most of the benefits, over domestic groups, which bear most of the associated risks and costs [11]. In these segments, the trend is the continued loss of domestic participation in the business, since the wealth generated today no longer contributes to the growth of local economic groups. This situation occurs in 25 (34%) of the 73 segments evaluated in the 12 supply chains researched.

5.2. Domestic Participation (Partly with State Support)

There are also supply chains and segments with greater control by domestic economic groups. In this case, agricultural production (primary production on farms) stands out, with practically all chains (except aquaculture) controlled by Brazilian producers. Examples of greater domestic participation also include:

- Baru, açaí, organic and natural rubber supply chains
- Farming production segments (rural producers), seeds for pasture in the beef supply chain, sugarcane varieties, and commercialization in several chains such as beef, chicken, tomatoes and rubber.

Characteristically, these are segments that rely on support from public policies, as in the case of farmers who benefit from subsidized credit from agricultural policy or the meat processing segment (including JBS) that received contributions from the BNDESPar bank. In part, it can be said that these are segments subsidized by the state, generating lose–win situations that do not impact the increase in overall productivity [72], as they privilege only specific groups (farmers that access credit or companies directly supported by BNDESPar, for example) and not the entire sector from public money.

On the other hand, there are segments with more extensive state support, such as the development of pasture seeds and sugarcane varieties by research networks such as Embrapa and Ridesa in partnership with private domestic companies. These investments made in science and technology tend to support the development of the sector as a whole, not only specific groups, generating win–win situations that lead to increased productivity throughout the sector [19], more domestic public and private investments, and favor the opening of the market to foreign investments.

Of the 73 segments evaluated in the 12 supply chains studied, 27 (37%) are controlled by Brazilian groups. Of these, 12 (44%) received direct support from the state, of which two (17%) went to specific individuals and companies and 10 (83%) went to science and technology investments for the benefit of the sector in a diffuse manner.

5.3. Mixed Segments—No Dominance

We observed no dominance of investments by foreign corporations or domestic companies in the following segments and supply chains:

- With the exception of animal health, mixed segments dominate the other sectors in the aquaculture supply chain.
- Feed for cattle, chicken and fish, and machinery and processing and commercialization in several chains.

Typically, these are segments with medium-intensity technology, usually not protected by patents. These segments can be considered win–win because they rely on foreign and domestic private investments without the need for direct public investments. Of the 73 segments evaluated in the 12 supply chains studied, 21 (29%) are equivalent to mixed segments.

5.4. Implications/Lessons on Investment Arrangements

The economic opening of the 1990s boosted Brazilian agribusiness [15] by attracting foreign investments [12] that were added to domestic private and public investments [16]. Investments from different sources were identified in the supply chains analyzed:

(1) Foreign direct investments (FDI) leading to two types of arrangements. The first, of the win–lose type, promoted advantages for foreign groups in relation to domestic groups, and resulted in complete supply chains (soybean chain) and/or segments of several chains (patented transgenic seeds and high technology machinery and implements in the soybean and corn chains) dominated by foreign capital. The second, of the win–win type, promoted mutual gains for Brazilian and foreign companies from mixed segments in which domestic capital was combined with foreign capital for the development of certain sectors, such as feed for cattle and chicken, processing and marketing, and machinery and implements, in several of the chains studied.

(2) Private domestic investments of the win–win type, which promoted gains for national capital allowing the growth and consolidation of domestic groups in some segments, such as seedlings in the sugar cane, cocoa and rubber chains, seeds in the açai and organic chains, animal feed in the beef and chicken chains, and commercialization in the beef and rubber chains.

(3) Public investments resulting in two arrangements. The first, of the win–win type, promoted the growth of domestic groups in some segments, such as pasture seed and sugarcane varieties, from the influx of investments in science and technology to the benefit of all. The second, of the lose–win type, promoted unequal growth among domestic groups by creating privileges for a few and benefiting specific production and processing (expansion of industrial plants) segments, with benefits for

some individuals (some large farmers) and organizations (beef processing giants for example).

This study adds to the existing literature on foreign direct investment (FDI) by multinational enterprises and the outcomes for the host countries [9]. It reveals whether and to what degree domestic entrepreneurs can benefit from the economic dynamics promoted by FDI by establishing themselves in the marketplace while competing with multinational foreign enterprises [12]. This study reveals that the effects of FDI are heterogeneous and conditional on local factors such as the absorptive capacity of the host economy [10]. We particularly reveal win–win scenarios in which both domestic and foreign investments supported dynamic segments of the agribusiness in Brazil.

6. Conclusions

Common sense has led Brazil to be seen as the prime example of agribusiness development worldwide. This study reveals that the reality is much more complex, with foreign multinational corporations controlling most of the agro-industrial segments of agribusiness carried out in Brazil and Brazilian companies having larger market shares mainly in the farming sector. Since agro-industrial segments can better remunerate capital and labor than farming, this study explores how domestic entrepreneurs can benefit from the thriving global agribusiness by establishing themselves in agro-industrial segments.

The ongoing investments and transformations in agribusiness supply chains offer new opportunities for economic growth in developing countries. Different market arrangements have provided for the allocation of large investments in Brazilian agribusiness, especially (1) foreign direct investments, (2) private domestic investments and (3) public investments in some segments. These different arrangements present in different supply chains are fundamental in explaining the recent great expansion of the sector in the country.

This study revealed that these different investments have distinct implications for the future of Brazilian agribusiness. Win–win arrangements rely on domestic investments and benefit from foreign investments, mutually benefiting domestic and international groups and increasing the productivity of the entire sector, and are thereby beneficial to the country in the short and long term. These are typical cases of the mixed segments in which there are no barriers preventing the entry of local groups (such as patents, very high technological knowledge or a great deal of invested capital). There are also some cases of policies aimed at developing technology in partnership with local companies. These are the arrangements that should be encouraged in the country.

Win–lose arrangements have led to the dominance of foreign groups in supply chains as a whole or in segments protected by patents or intensive in cutting-edge technology, hindering the entry of domestic capital. Lose–win arrangements have promoted unequal investments, based on economic subsidies that favor only a few to the detriment of many and do not contribute to the growth of the economic sector as a whole or even of the entire supply chain. These are the types of arrangements that should not be encouraged by Brazil, especially in the long run, since they result in more economic disadvantages for domestic groups.

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Article

Can Family Farmers Thrive in Commodity Markets? Quantitative Evidence on the Heterogeneity in Long Agribusiness Supply Chains

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Abstract: *Background*: Family farmers' participation in marketing channels has prompted debates on the types of market best suited to this type of farmer. Commodity production by rural communities and the role of agribusiness long marketing channels for family-based farmers are the subjects of numerous qualitative studies. However, quantitative studies capable of assessing the relevance of long channels to family-based farmers are scarce. Therefore, this study intends to assess the relevance of long marketing channels for family farmers. *Methods*: We compiled the data from the survey responses of family farmers from 155 municipalities in a state in the central region of Brazil. *Results*: (1) There was an economic concentration of some marketing channels, namely, the sale of commodities occurred in 35% of the municipalities and included 4.15% of the sampled family farmers. The income derived through these channels represented 2.13% of the farmers' total income included in the study. (2) There is a low diversity of market types. On average, we found 2.95 long marketing channels per municipality. (3) Family farmers' participation is low in most commodity long channels. Between 0.11% and 4.15% of the family farmers in the sampled municipalities participate in these channels. Long channels linked to the cattle production chain showed more relevant capacity for inclusion. *Conclusions*: Contrary to the expectations of those behind initiatives to promote the marketing and sale of locally-sourced commodities within rural communities, agribusiness long marketing channels provide limited opportunities for family farmers to market their goods.

Keywords: rural development; agri-food systems; alternative models; agriculture; Brazil

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1. Introduction

Family farmers' participation in commodity supply chains has considerably increased in South American countries in recent years, due to the increase in worldwide demand for agricultural produce and the increase in the prices of such products in global markets [1]. This process has contributed to the emergence of a group of highly technified family farmers integrated into the markets. However, it has promoted other developments in the agrarian market's dynamic, such as the weakening of the rural communities involved due to a greater dependence by farmers on external resources, with a related reduction in their autonomy [1].

Studies have shown that the only way for small-scale agriculture to survive the modernization process is to adopt new technologies and participate in large commodity markets [2]. Others studies point to the weaknesses of this process of inclusion in modern agro-industrial systems [3]. However, there is a lack of research that quantifies the social and economic relevance of the processes mentioned above to family farmers. Studies have shown several potential bottlenecks of this inclusion process [4,5], but the lack of quantitative investigation has made it difficult to deepen the analysis of the role of different markets in the rural development process. Thus, this study seeks to help fill this gap.

This study focuses on the opportunities and limitations for inserting family farmers in long commodity marketing channels. We sought to investigate to what extent such channels can promote the inclusion of family farmers. Thus, this study aimed to assess the capacity of long marketing channels to include and generate income for family farmers.

The specific research objectives of this study were to: (1) identify and spatialize the diversity of long marketing channels available to family farmers in the municipalities of the Brazilian state of Goiás; (2) quantify the participation of family farmers in different long marketing channels; and (3) assess the economic relevance of this type of commercialization to the income of family farmers in Goiás.

2. Literature Review

2.1. Concepts: Long and Short Channels, Agribusiness and Family Farming

Long channels are agro-industrial supply chains that involve an extensive network of intermediary agents that generate standardized products without identity through weak or non-existent relationships between producer and consumer and production and consumption [6]. We can characterize short supply channels (which, in the relevant literature, are called short food supply chains) according to two dimensions. The first relates to the organizational structure through which the product is marketed and can be of three types—direct sales, spatial proximity, or spatially extended. The second dimension relates to the qualitative definition of the product itself (organic, agroecological, healthy, local, regional, traditional, among others) [7].

Short supply channels are not necessarily an alternative to long channels [8], nor are they the antithesis of long channels, or in a diametrically opposite position in agri-food systems [9]. In the same way, we cannot analyze short channels and long channels through the lens of dichotomy [9], as agribusiness and family farming are not necessarily antagonistic social and productive categories either [10].

Despite the construction and consolidation of the concept of agribusiness being the subject of a complex political, academic, and social dispute [11], we can understand agribusiness to be the set of operations and transactions that occur downstream, upstream, and within agricultural units. Therefore, they involve both the production of inputs and machinery, services, processing, and marketing, as well as agricultural production itself [12].

In Brazil, to be legally classified as a family farmer, it is necessary to meet the criteria established by Law 11,326/2006 and the MDA Ordinance n. 102/2012 [13]. In general, we can deem a family farmer as a person who mainly employs family labor, whose family income comes mainly from agricultural production generated within a rural household, and whose farming area does not extend beyond four fiscal modules. According to the municipality, a fiscal module in the state of Goiás varies between 16 and 70 hectares.

2.2. The Productive Inclusion of Family Farmers in Markets

Promoting the development of family farms in Brazil presents several obstacles. First of all, the implementation of public policies can limit the potential of family farmers, as different groups are treated as equals. Few regions have favorable conditions for developing modern family farms, and few farmers are in a favorable position vis-à-vis the established markets. Such conditions may explain the fact that less than 25% of Brazilian family farmers are integrated into these markets [14].

Market integration can be a driving force behind family farming, as the more significant the integration, the greater the income in this category [14]. In recent years, there has been a concomitant increase in the production of various agricultural products (mainly agricultural commodities) in Brazil and a decrease in the number of rural establishments producing such products. This demonstrates that a concentration process has taken place in these production systems, explained by the need to specialize production to reduce costs and increase scale. This is reflected in many family farmers' departure from production chains, such as those linked to integration systems with large agribusinesses and contract agriculture [15].

The inclusion of family-based farmers in marketing circuits as a strategy for promoting rural development seems to be something crystallized in the literature [16,17]. The discussion about the types of commercialization that value family farmers and promote the endogenous development of rural communities [18] must also take into account factors that (in the context of national rural development) weaken some chains by having a large part of the links transnationalized [19,20]. Thus, it is necessary to deepen studies on the relevance of the productive inclusion of family farmers in long marketing channels and the consequences of this process in rural development.

We can find three strands in the literature that analyze the insertion of family farmers: the first defends the thesis that it is necessary to insert family farmers in conventional production chains and provide support so that they can compete with large producers—long marketing channels [21]; the second current defends the need to strengthen and create new marketing channels based on reciprocity, territoriality and trust—short sale channels [6]; and the third current presupposes an analysis of the inclusion of family-based farmers under the lens of interaction and coexistence between short and long channels—the coexistence of markets [9].

We can consider the strategy, by some theorists, of including family farmers in long production and marketing channels (commodity chains, for example) as the easiest and fastest alternative for the productive inclusion process of this category and the poverty reduction of rural populations [22]. Therefore, viable marketing channels for family farmers would be the large hegemonic chains (however, we would condition this participation to articulation in associations and cooperatives) and market niches. However, we know a significant portion of this category cannot enter such marketing modalities [23]. The inclusion of family farmers in long marketing channels has been greatly encouraged through public policies of the Brazilian State, mainly in support of soybean cultivation for the production of biodiesel [24].

We also know that family farmers sell their products in different marketing modalities and that long channels are one of these modalities. One of the factors that condition the ability of family farmers to enter and remain in the long channel is the specialization and technification of their production systems [2]. In Brazil, these characteristics are not recurrent among family farmers [25]. From this context emerges the hypothesis that the long channels cannot include many Brazilian family farmers.

Moreover, we can explain the difficulty of family farmers to access markets by the lack of access to production and communication technologies [14]. With the emergence of advanced technologies in agriculture and supply chains, this difficulty can be increased, especially when it comes to the inclusion of family farmers in long channels.

2.3. Advanced Technologies and the Participation of Family Farmers in Agricultural Markets

The use of advanced technologies in different links of the supply chain is growing. Blockchain technology is one of the prominent examples of this process that presents both potential and challenges, especially when it comes to the inclusion of small-scale farmers. This technology guarantees transparency in transactions, traceability of products and production processes, and helps in the governance of supply chains. It has great potential to help family farmer cooperatives increase their competitiveness in inserting their products into long marketing channels. However, such technology is still not very accessible, and demands an extensive information infrastructure and know-how that are not always present in family farmer organizations [26].

2.4. Family Farmers in Long Channels: Lessons and Experiences from Other Countries

The long channels operate with different logics in different countries, presenting differences and similarities regarding the participation of agents from rural communities. Thus, it is necessary to review the literature on the subject in the different realities of countries to understand how family-based farmers participate in long channels, and to identify their challenges and opportunities. Family farmers' participation in long marketing channels occurs in very heterogeneous ways, and is different in each country in the world.

The vertiginous increase in soy-planted areas in South America has brought several environmental, social, and political consequences to the territories of these countries. In Argentina, it has impacted ways of life of rural communities, provided the reconfiguration of work processes for members of rural families, and contributed to family farmers leaving their agricultural activities in search of wages on soy farms, causing new population flows between regions [27].

Encouraging the insertion of Paraguayan family farmers into the soybean chain led to the differentiation of this social category into two groups: (1) few technified farmers capable of leasing more and more areas; and (2) many indebted farmers who lost their land to pay debts incurred to enable soybean production [1].

The strengthening and growth of large dairy and milk processing companies have, to a certain extent, led to a process of loss of identity for Canadian family farmers who produce milk. Milk and its derivatives, which were previously products that symbolized the approximation between people from the countryside and the city (through the construction of the social value of the products), became impersonal and standardized foods, distancing producers from consumers [28].

Rising global demand for Mexican tequila has contributed to mergers of large beverage companies and acquisitions by transnational corporations of local ventures. Thus, with the growing demand, some Mexican family farmers started to implement agave monocultures, reducing their productive diversity, and others rented their land to large producers, losing autonomy [29].

In South Africa, large supermarkets are increasingly becoming the leading players in the fruit, vegetable, and processed food markets. Although this commercialization channel was not able to include a significant portion of family farmers in that country, it demonstrated the ability to create strategies, protocols, and a chain governance model that promoted the professionalization and productive inclusion of a relatively large number of farmers who were previously excluded from the markets [30].

In some societies, the middleman or intermediary figure in the marketing channels is seen as harmful to agri-food systems, as it supposedly appropriates a large part of the farmers' profit margin. In Papua New Guinea, the population increase in urban centers and the increase and differentiation in demand for food provided a more significant insertion of intermediaries in agri-food systems. This process was necessary to dynamize the mercantile food exchange processes and productive specialization and reduce transaction costs for family farmers. On the other hand, it reduced the earnings of some farmers and excluded others from participating in city fresh food markets [31].

In all previous experiences, family farmers' participation in long channels affected their livelihoods. Some mentioned the consequences of this process in territorial configuration, others in the professionalization of family farmers, others in the dynamization of supply chains, but none addressed the ability to include family farmers in different long channels.

2.5. Gaps in Previous Studies and Contributions of This Research

Studies on family farmers' participation in long marketing channels address the challenges and opportunities of this process without quantifying the capacity of this type of channel to include small farmers. This gap makes it difficult to understand the real potential that these channels represent for the development of Brazilian family farmers. This study addresses this gap by quantifying the capacity of agribusiness long supply chains to include family farmers. This is considered for each of the different long marketing channels, and thus we seek to contribute to the literature by revealing the heterogeneity of long channels and the importance of channel diversity (long and short).

3. Materials and Methods

The low availability of data in the Brazilian Agricultural Censuses regarding the commercialization of family farmers is an obstacle to rural development studies. The 2017 Agricultural Census, as well as the previous ones, gathered data related to different production types (plant extraction, agroindustry, fruit growing, horticulture, temporary farming, permanent farming, and livestock), taking into account aspects of production such as volume produced, technologies used, value and sales volumes, and the profile and condition of the farmer. However, no data were collected concerning how products are marketed. Thus, it is possible, for example, to know the milk volume produced in a particular region or municipality, the sales volume from milk, and the technology used in production. However, agricultural censuses do not generate information that indicates how the milk was sold. Therefore, territories with great economic dynamics are invisible to the public authorities.

The geographic outline of this study is the state of Goiás, located in the central region of Brazil. Goiás is a state that has incentives from the national government for the production of large-scale commodity crops such as soy, corn, cotton, and sugarcane, as well as for dairy and beef cattle raising. All of these farming systems are capitalist [32]. However, family farming is also a relevant segment within the state, and is responsible for 38% of the gross agricultural value production (IBGE, 2017). Therefore, we decided to investigate the importance of long marketing supply chains in developing family farming in the state of Goiás.

Discussions were initially held with researchers in the field of rural studies to define the profile of the survey respondents. We defined that they should be figures who worked with family farmers in the municipalities. After informal conversations with family farming leaders, we concluded that the Goiás Agency for Technical Assistance, Rural Extension and Agricultural Research of Goiás (EMATER/GO) would be an institution with the capillarity and the ability to gather information regarding the marketing processes of family farmers in the 246 municipalities in the state. Thus, through a partnership between *EMATER* and the Graduate Program in Agribusiness at the Federal University of Goiás (PPGAGRO-UFG), an action plan was designed to collect data on the marketing practiced by family farmers in the state of Goiás.

Meetings were initially held between the research team and the directing board of EMATER to show the relevance of the research in the context of rural development in the region. Then, we held meetings with the coordinators of each EMATER regional office. Such meetings were fundamental to identifying the different types of marketing channels in the municipalities. Accordingly, the regional coordinators categorized each channel as short or long. During this process, a survey was developed with contributions from EMATER regional coordinators and the board of directors, and then sent to field technicians at the EMATER Local Units (LU). The regional coordinators held training meetings with technicians from the local units to categorize the marketing channels available to family farmers.

We instructed the LU technicians to identify the family farmers' leaders from each of the commercialization channels in each municipality. Thus, the responses to the survey for each municipality were collectively constructed from the communication between the LU technicians and the key informants of each sales channel.

We e-mailed the survey to LU technicians via the Google Forms platform. We divided the survey into two sections: (1) long marketing channels available to family farmers in the municipality, and (2) short marketing channels available to family farmers in the municipality. The most frequent long and short channels in the state were listed, and respondents answered two questions for each channel: (1) whether or not family farmers participated in the channel, and (2) how many family farmers participated in the channel. We obtained a response from 155 of the 246 municipalities in Goiás. Among the 155 municipalities that sent the completed survey, we selected 75 to respond to the second survey referring to the economic performance of each sales channel. Of these 75 municipalities, only 58 responded.

In this economic performance survey, we made just one question per marketing channel: how many Brazilian reals (gross income) does the set of family farmers in the municipality participating in the channel receive per month? In turn, the sum of the income obtained by the set of family farmers sampled in each channel was obtained with the data obtained from this question. The sums obtained by sales in all short and long channels were considered the income universe (100%). Therefore, this percentage variable was called productive income from each channel, which expresses the share of income obtained in each channel compared to the total income obtained in all channels.

Next, the research step obtained data referring to the presence of marketing channels and family farmers' participation from 63.01% of the municipalities in Goiás. Economic performance data of the marketing channels were obtained from 37.41% of the sampled municipalities, representing 23.57% of the municipalities in Goiás. We used the number of rural family households obtained in the 2017 Agricultural Census of the Brazilian Institute of Geography and Statistics (IBGE) as the universe in each municipality. Many farmers participated in more than one marketing channel, making it impossible to gather information regarding the number of family farmers participating in long channels. For this reason, the "number of long-channel marketing posts occupied by family farmers in each municipality" variable was created, which we calculated through the sum of the number of family farmers participating in each long channel modality in the municipality.

We collected the data between August 2020 and March 2021. We also used some strategies to ensure the quality of the data collected by LU technicians. After receiving the completed forms, calls were made to each of the LU technicians to check whether the data entered was faithful to the municipality's reality. During the calls, it was possible to assess whether local technicians had understood the research concepts properly. We did not consider the filled-in forms by technicians who did not understand the concepts. During the calls, it was also possible to understand if some outliers represented the reality of the municipality or if their data were collected in the wrong way, and therefore should not be included in the final database.

We completed the data processing as follows: we initially analyzed the municipalities regarding the diversity of marketing channels and family farmers' participation in each channel. Then, the marketing channels were analyzed, with their occurrence in the municipalities of Goiás and the participation of family farmers. In this study, we used means, deviations, and standard errors to measure some variables.

We also used the Qgis platform to prepare a map specializing in the number of long channels present in each municipality. We elaborated the maps using data collected during the study and information from the State Geoinformation System of the State Government of Goiás (SIEG).

The methods and tools mentioned allowed us to answer questions on the participation of family farmers in each of the commodity supply chains available in the Brazilian state of Goiás.

4. Results

4.1. Geographical Distribution and Diversity of Long Marketing Channels Available to Family Farmers

There is little diversity of long marketing channels available to family farmers in the sampled municipalities. Few municipalities had more than five channels, as shown in Figure 1. Southeast Goiás was the region with the most significant number of municipalities with many long channels. The central region of the state (around the capital Goiânia), the southwest region, and the region around the Federal District also had some municipalities with many long channels. The north and northeast of Goiás had few municipalities with many long channels.

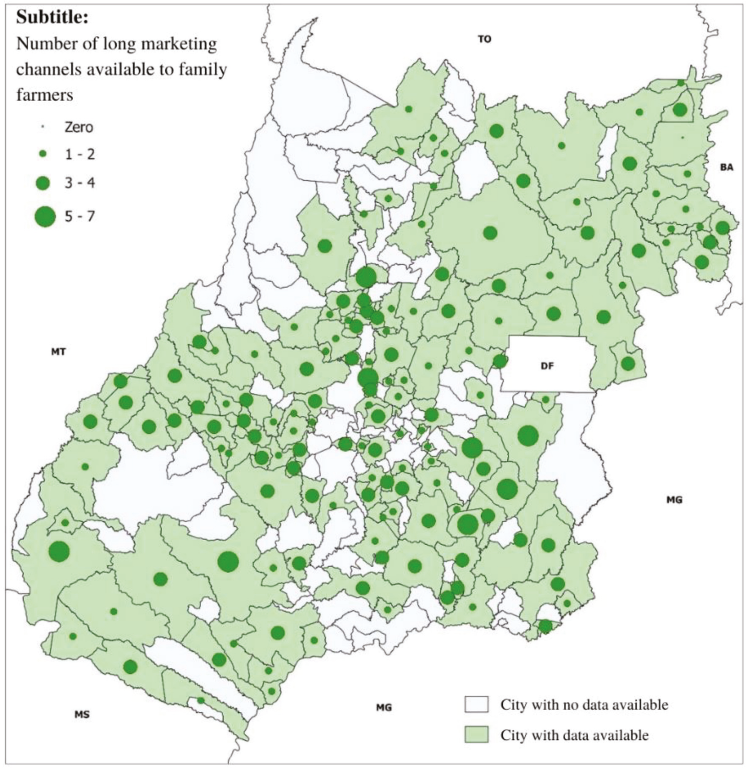

Figure 1. Map of the number of long marketing channels available to family farmers in Goiás.

The average number of long marketing channels available to family farmers, and an average number of marketing posts of the long channel-type available to family farmers, was low compared to the average number of rural family establishments in the sampled municipalities (Table 1).

Table 1. Mean, standard deviation, and standard error of the quantities of long canals, commercialization posts, and rural family establishments in the sampled municipalities.

	Mean	Standard Deviation	Standard Error
Number of long channels available to family farmers in each municipality in Goiás.	2.9548	1.2971	0.1041
Number of long-channel marketing posts occupied by family farmers in each municipality.	195.9493	261.6002	21.0122
Number of rural family establishments in the sampled municipalities.	461.3161	385.3826	30.9546

Source: Data collected in the study and IBGE, 2017.

Regarding the diversity of long commercial channel modalities existing in the municipalities of Goiás and the participation of family farmers in the channels, it was noticed that: (1) there are on average 2.95 long channels available to family farmers in each municipality; (2) there are on average 195.94 long marketing posts occupied by family farmers in each municipality; (3) in total there are 30,371 long-term commercialization posts occupied by family farmers in the sampled municipalities; and (4) the ratio between long-term commercialization posts and the number of rural family establishments is 42.47%. It should be noted that 42.47% of family farmers cannot be said to be part of long channels, as many participate in more than one marketing channel.

Figures 2 and 3 show the geographic distribution of the different long marketing channels existing in Goiás with family farmers' participation. There is a certain similarity between the maps of the channels for sales of milk to dairies and sales of cattle to slaughterhouses. The sales channel to agricultural market hubs was concentrated around Goiânia and around the Federal District. The sales channel to large supermarket chains was only presented in the horizontal strip located in the state's central portion of the southern region. The sales channel of agricultural commodities proved to be recurrent throughout the central–southern portion of the state and in part of the north and northeast of Goiás. Sales of extractive products from the Cerrado to middlemen were more recurrent in the state's north, northeast, and central–west regions. The presence of other long sale channels did not show a clear trend.

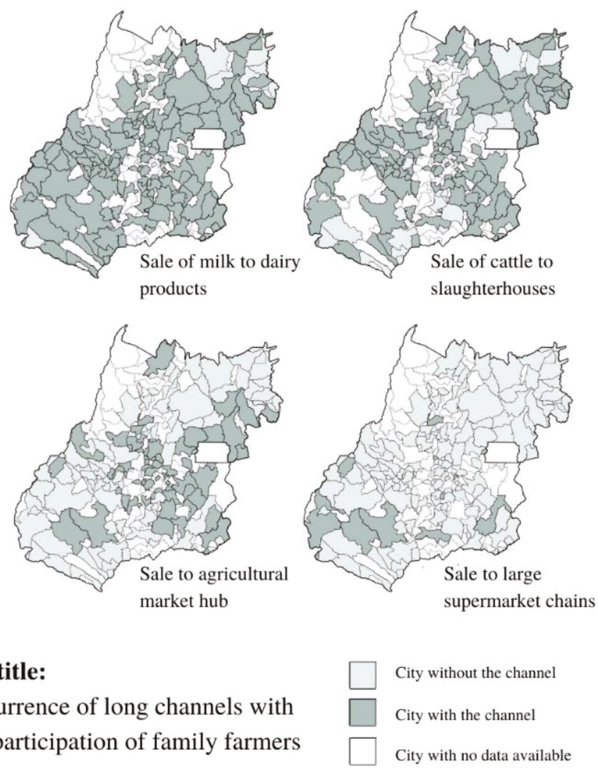

Figure 2. Presence of long sales channels with family farmers' participation (sale of milk to dairies, sale of cattle to slaughterhouses, sales to agricultural market hubs, and sales to large supermarket chains).

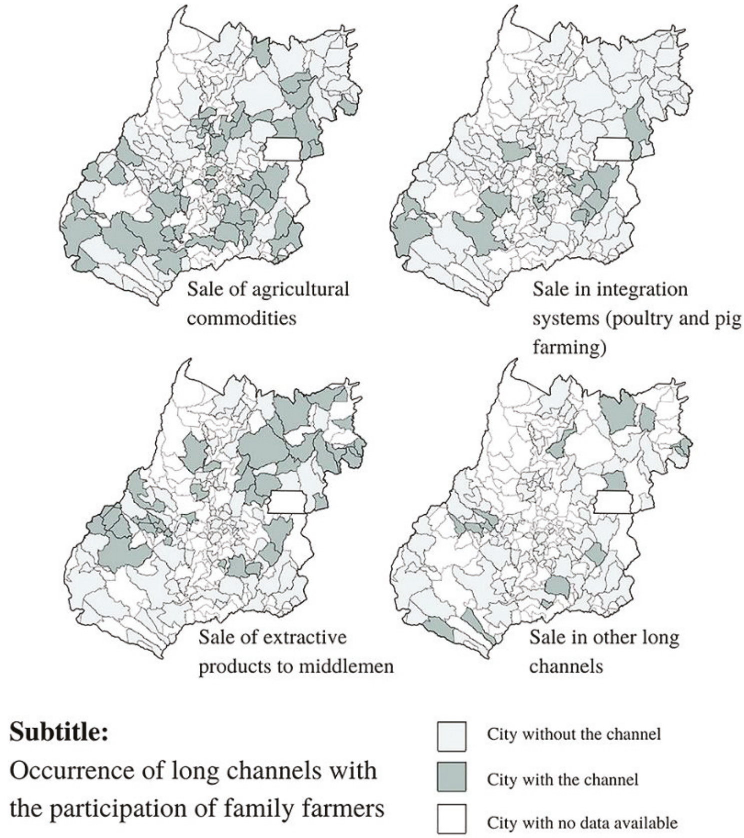

Figure 3. Presence of long sales channels with family farmers' participation (sale of agricultural commodities, sales in integration systems, sales of extractive products to middlemen, and sales in other long channels).

4.2. Participation of Family Farmers in Different Long Channels

Table 2 reveals a more significant share of family farmers in the long sales channel for the sale of milk to dairies and a small share in the sales channels of agricultural commodities and sales in integration systems.

The most recurrent channels in the municipalities and with the highest inclusion rate of family farmers are sales of milk to dairies, which occur in 92.21% of the municipalities and include 27.58% of family farmers, and sales of cattle to slaughterhouses or middlemen, which occur in 77.40% of the municipalities and include 11.79% of family farmers. The least recurrent long channels with the lowest inclusion index are sales to large supermarket chains, which occur in 7.33% of the municipalities and include 0.11% of family farmers, and the integration systems in 10.96% of municipalities, including 0.23% of family farmers. Furthermore, except for the channel for selling milk to dairies, the data revealed that the long marketing channels in Goiás are not very capable of promoting the productive inclusion of family farmers and not very capable of promoting such farmers in the agri-food systems of the studied municipalities.

Table 2. Participation of family farmers and occurrence of long marketing channels in the municipalities of Goiás.

	Family Farmers Participating in the Channel (%)	Municipalities in the State that Have the Channel with the Participation of Family Farmers (%)
Sale of milk to dairies	27.58	92.21
Sale to agricultural market hub	1.91	41.72
Sale of cattle to slaughterhouses or middlemen who resell to slaughterhouses	11.79	77.40
Sale to large supermarket chains	0.11	7.33
Sale of agricultural commodities (soybeans, corn, cotton, etc.)	4.15	35.53
Poultry and pork sales via large integration companies (Sadia, Superfrango, etc.)	0.23	10.96
Sale of fruits and other extractive products from the cerrado to middlemen	1.25	32.00
Other long marketing channels	0.7	10.32

4.3. Economic Relevance of Long Channels to the Group of Family Farmers

Regarding the economic performance of the different commercialization channels (Figure 4), the data revealed that: (1) the set of long channels is responsible for 75.35% of the gross income arising from the productive activities of family farmers; and (2) the long channels with the greatest economic weight were sales of milk to dairies and sales of cattle to slaughterhouses and middlemen, respectively, representing 33.30% and 21.15% of gross revenues from the productive activities of the group of family farmers sampled. It is also noted in Figure 4 that the short sales channels represent almost 25% of the productive income of family farmers in Goiás.

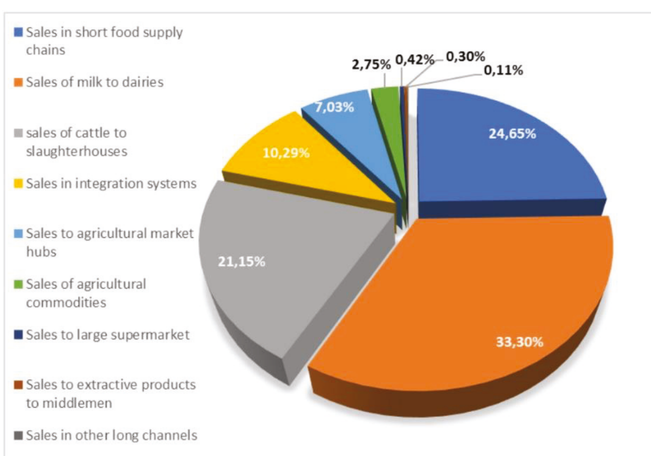

Figure 4. Participation of different marketing channels in the gross productive income of family farmers.

In analyzing Table 2 and Figure 4 together, we can see that although the sales channel in integration systems demonstrates specific economic relevance (representing 10.29% of the income of the sampled family farmers) and spatial relevance (occurring in 16 of the 155 municipalities sampled—10.96%), only 0.23% of family farmers participate in this type of commercialization. In other words, it is a channel that generates significant income, but only for a few farmers.

The long sales channel for commodities showed little economic relevance, representing only 2.75% of the productive income of the sampled family farmers, with low participation of farmers (4.15%), and significant occurrence in municipalities being present in 35.53% of the municipalities sampled.

5. Discussion

Few municipalities sampled had more than three types of long marketing channels with family farmers' participation. This is due to two reasons: first, the success and sustainability of these farmers' participation in these channels over time depend on chain coordination and state support [30]. The coordination and governance of long chains take place vertically, meaning without the participation of all actors. In addition, state support for family farmers in Brazil occurs intermittently, varying according to the managers who assume the municipal, state, and federal public powers. These factors make the participation of family farmers subject to specific realities. Another possible reason for the low diversity of long channels is the precarious infrastructure conditions of the municipalities. The operations of these channels largely depend on a configuration that facilitates logistical aspects of the production, distribution, and consumption processes.

Large agri-food chains force participating family farmers to specialize their production and reduce their productive diversity [29]. Due to the small scale of family-based production, their relevance in long channels is minor, meaning they are not protagonists in these exchange processes. The search for recognizing family farmers as a category and social group in society involves their participation in markets capable of explaining their specificities and potentials [18].

The discourse of dairy aptitude in Goiás as something consolidated and indisputable is striking in several meetings, events, and actions with agents of public power and organized civil society. However, such discourse does not usually go beyond the issue of fresh milk. When discussing municipal inspection systems, agro-industrialization, and milk processing, the main difficulty for family farmers is perceived as operationalizing the milk chain so that the family farmer is not a mere milk supplier to large dairies. A factor that corroborates this hypothesis is the low occurrence of special cheeses with specific characteristics of the territories (only Cabacinha cheese in the Parque das Emas territory) and the shallow index of municipalities with the Municipal Inspection System in operation.

The long channel with the greatest occurrence in the municipalities and the greatest participation of family farmers was the sale of milk to dairies. However, even though it is the channel with the greatest participation, there was a lower rate than expected (27.8% of family farmers in the sampled municipalities), since the state's great dairy aptitude is a culturally well-established attribute in Goiana. These data support several hypotheses: the first is that many family farmers are inserted into the milk chain, but few are inserted into the long sales channel of selling milk to dairies, meaning there is a lot of milk production being sold and consumed, but it remains invisible. Another factor that may explain this fact is that the modality of selling milk to dairy products promotes an impersonalization of products produced by family farmers [29], which, together with the high production costs and the low earnings of the activity [7], economically and culturally discourages family farmers from selling their products through this channel.

A significant portion of municipalities have family farmers selling their products to middlemen, with 41.72% to intermediaries who resell in agricultural market hubs, and 32% to intermediaries who buy and resell fruits and products from the Cerrado. This demonstrates the importance of this agent in the agri-food systems of municipalities, especially those that are not close to urban consumer centers. Such intermediaries play a relevant role in the supply of municipalities and significantly interfere in food dynamics. They supply municipalities with products from agricultural market hubs and supply agricultural market hubs with products from municipalities. To a certain extent, this practice hinders the consolidation of alternative food networks and the construction short marketing channels, enabling the productive inclusion of farmers who do not have a commercial profile.

However, these marketing channels occur more frequently in municipalities located on the margins of major state and federal highways, restricting the participation of farmers from more remote municipalities. Although they occur in many municipalities, long channels centered on the figure of the middleman present a very low participation of family farmers, demonstrating the need for the productive specialization of farmers and an improvement in the coordination of chains [31].

Among those investigated, the two long channels that attracted the most attention about family farmers' participation were the sales of agricultural commodities and sales in integration systems. Family farmers' participation in these channels was greatly encouraged through public policies. In recent years (2017 and 2018), 40% of the funding resources allocated to the National Program for Strengthening Family Agriculture (*PRONAF*) were allocated to financing soybean crops [1]. Another great public power incentive for the insertion of family farmers in long channels was the Biodiesel Social Seal, which encouraged many farmers to start planting soybeans [24]. In other words, the contribution of public resources and the incentive by the state to insert family farmers in these channels did not necessarily generate a greater inclusion of farmers.

Family farmers' participation in these long marketing channels, which force intense production specialization and decrease the diversity of agroecosystems in family units, generates intense socio-territorial transformations and other negative impacts [1,27]. The data from this study revealed that these impacts, already discussed in the literature, are not compensated by the production of significant income for the group of family farmers.

Only 3.64% of the productive income of the sampled family farmers comes from participation in agricultural commodity chains, meaning that it is a channel that generates little income for the category. Moreover, in addition to generating little income for local family farmers, it mostly moves the economy of transnational companies downstream and upstream of production [19,20]. In other words, the long channels with greater support from the state and greater political appeal (under the discourse of efficiency, productivity, and income generation) were those with the lowest economic participation in the productive income of the group of sampled family farmers.

The data revealed that short sales channels, even in a state markedly hegemonized by large-scale production [32], are relevant for the economic reproduction of family farmers. The set of short channels accounted for 24.65% of the productive income of the group of sampled family farmers, and the set of long channels accounted for 75.35%. This data supports the hypothesis of coexistence between long and short sales channels. In some moments, they feed back and converge, and in others, they dispute and diverge [9].

Family farming and agribusiness are not antitheses [10], but there is a great diversity of social, environmental, and productive conditions that interfere with the performance of family farmers in the marketing channels [14]. For a portion of family farmers, who have more technical ability and greater competitive attributes, long channels are a possibility [2]. Nevertheless, agribusiness and agro-industrial chains are not open to participation for a much larger portion of family farmers. The cited studies discuss the reasons for not inserting a portion of this category and some impacts that such insertion can cause. On the other hand, the results of this research quantitatively reveal the inability of agribusiness agro-industrial chains to include and generate income in a significant way for family farmers. The results also reveal that short channels are configured as a potential alternative for inclusion and income generation for family farmers excluded from long channels.

6. Conclusions

This study presents empirical evidence of the heterogeneity of food supply chains that are better suited to family farmers, and how this affects farmers' capacity to market their agricultural goods. Agribusiness long marketing channels are different from those expected by initiatives promoting commodities as a solution for the development of rural communities, as they provide limited opportunities for family farmers to market their goods.

A large part of the sampled municipalities had less than three types of long marketing channels in which family farmers could participate, and only a small portion of the municipalities had more than five long marketing channels, revealing few options for family farmers to outflow production via long channels. The sale of commodities occurred in 35% of the municipalities, 4.15% included local family farmers, accounting for 2.13% of the sampled farmers' income from farming activities.

The only long marketing channels with a large participation of family farmers were the sale of milk to the dairy industry and the sale of cattle to slaughterhouses, or middlemen. All other agribusiness long channels proved to be fairly closed to the participation of family-based farmers, with a participation rate ranging from 0.11% to 4.15%.

Despite being present in 35.53% of the municipalities in the state of Goiás, the commodity long marketing channels were relevant to only 2.75% of the sampled family farmers. The sales channel in integration systems showed greater economic participation, but with a reduced number of participating family farmers, revealing a concentration in the long marketing channels.

As a whole, long channels are hardly capable of including a large portion of family farmers and are responsible for a low percentage of farming income for these farmers. These findings reveal the need to explore the possibilities of non-commodity goods in short food supply chains, in which farmers market directly to consumers as a complementary development approach. An important starting point for this effort is to recognize the heterogeneity of food supply chain arrangements (including both long and short supply chains) in terms of opportunities for family farmers to market their agricultural goods.

This study focused on quantifying the participation of family farmers in commodity supply chains and the economic relevance of such channels for family farmers' income. Causal relationships that explain the level of family farmers' participation in each type of long channel were not established in this research, which is a possible agenda for future studies. Another challenge for future research is to quantify the capacity that short food supply chains have to include family farmers and generate income for these farmers.

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Data Availability Statement: Data presented in this study are available upon request to the author for correspondence. The data are not publicly available yet, as they will be used in future studies that will be submitted to journals that require originality.

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The Logic of Collective Action for Rural Warehouse Condominiums

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Abstract: *Background:* Given several bottlenecks in Brazil in distribution logistics, mainly in transport and warehouse activities, some new forms of collective action have appeared. The Condominiums of Rural Warehouses was conceived of to overcome these bottlenecks and provide better income and competitiveness to small producers in agribusiness. This article aims to analyse aspects of collective action with the focus of Rural Condominiums in the context of Brazilian agribusiness. *Methods:* We conducted exploratory, descriptive and qualitative research under the Theory of Logic of Collective Action lens for this purpose. Besides conducting a literature review, we conducted a semi-structured interview with the managers of the Rural Warehouse Condominiums. We analysed the data through a Categorial Content Analysis. *Results:* The main results show an approximation of the rural model of the Condominiums of Rural Warehouses with the Theory of Logic of Collective Action, mainly for small producers. *Conclusions:* We highlight the feasibility of the warehouse structure collectively, as it strengthens and provides greater efficiency to rural business and producers, inserts and integrates the industry into a competitive market environment, provides economic and social benefits, leads to cost reduction, and increased profit. The economic, social and logistical determinants show the product's commercialisation, logistical gains, and the producers' association regarding the development and growth of rural collective action. This paper can be helpful for practitioners and researchers interested in this field.

Keywords: collective action theory of logic; collective actions; rural warehouse condominiums

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1. Introduction

Agriculture is subject to constant economic, social, political, and technological changes. Many of these changes arise to solve problems in the field of agribusiness, to increase the profitability of the system and its competitiveness, and to reduce costs. In this context, agriculture starts to be perceived in a systemic way, with the agricultural business, through relationships intertwined in a complex system of activities and participants, called agribusiness [1,2].

In Brazil, agribusiness accounts for about 43.2% of the country's total exports, providing economic growth, development, and competitiveness [3]. Despite the great representativeness and importance, Brazilian agribusiness faces some difficulties, problems and risks in terms of rural activity [4–7]. The worldwide growing demand for Brazilian commodities, driven by countries with large populations such as China [8], at the same time creates opportunities for Brazilian farmers in emerging markets [9] and challenges them to overcome the logistic obstacles.

Among these obstacles and particularities are: (i) the bottlenecks caused by inefficient and inadequate distribution logistics and infrastructure problems [10–14]; (ii) exclusion and social conflicts [15]; (iii) numerous, small, poorly organised, distributed and distant rural producers throughout the territory [2]; (iv) production seasonality [2,16]; (v) perishability of agricultural products [2]; (vi) weather, pests and diseases; variations in supply and demand; and (vii) difficult price and production predictability [16].

Given this, Rural Collective Actions present themselves to face and circumvent the difficulties and particularities of the agricultural business and to achieve gains and advantages. Rural collective action can: (i) promote social, technological and innovative development; (ii) add value and create wealth [17–24]; (iii) assist in decision making; (iv) maximise the profit of associates and provision of goods or services [25]; (v) is more efficient than disorganised individual actions [26]; (vi) generate the dilution of activity costs [27,28]; (vii) assist in the commercialisation of and access to production resources for small farmers, provide technical assistance to members, access to market information, and provide an advantage with transport and storage [29]; and (viii) provide a market advantage in the commercialisation of production [30].

Thus, different models of Rural Collective Actions emerge [8,9,22,29–31], and each type of model has its characteristics and specificities. The variation may be due to the forms of association, size, incentives adopted [25,26], or dynamic nature [32], and it is essential to understand the reasons for the variability between the different forms of Collective Actions [32,33].

Specifically, in this study, the collective actions are formed by social actors or groups that act as a collective [17,19], who can use experience for guidance, understanding, and set rules for actors participating in the action [19], by considering common goals [26]. These joint actions attempt to constitute a collective good, more or less formalised and institutionalised, through people who aim to achieve common goals through cooperation and competition with other collectives [19].

Thus, the objective of this study is to investigate the emerging form of collective action of Condominiums of Rural Warehouses [22,31] under the lens of the Theory of Logic of Collective Action proposed by Mancur Olson (1965). In the context of rural collective actions, the inefficient distribution logistics and the shortage of warehouses in the country are the primary motivations for this study.

Mainly, this study empirically evidences collective actions and those social actors and/or rural producer groups that present themselves as collective subjects. It also provides evidence and criteria to guide, understand, and govern actions based on shared objectives. Thus, for the participants of this study, the joint effort is an attempt to constitute a collective good, more or less formalised and institutionalised, with people who seek to achieve common goals through cooperation and competition with other groups in distinct collective actions.

The Condominiums of Rural Warehouses is a unique collective action model in Brazil, which does not fit the characteristics of other forms of collective action. Usually, the problems of cooperation and free-riding arise in managing collective resources. The new model of rural collective actions, with an associative and cooperative character formed by neighbouring farmers, minimises the two previous problems. Rural producers collectively contribute financial and physical resources. Then, after constructing the warehouse, they share the structure by dividing them into storage quotas. This structure of shared financial quotas makes it possible to reduce the warehouse deficit and other logistical bottlenecks, mainly related to transportation. Besides that, co-producers reduce unnecessary costs, trade production without intermediaries and obtain advantages from the condominium and storage system [11,27,28,31,34]. The paper shows that this collective rural warehouse management model succeeds because it follows the theoretical model of Olson's Collective Action Logic. Literature on the subject is still scarce, and no study has, as of yet, analysed Brazil's issue. Finally, Olson's Collective Action Logic Theory explains the new rural management model related to the condominiums of rural warehouses.

2. Theory of Logic of Collective Action

Mancur Olson was an American economist and social scientist who studied social and political phenomena from economic models. "The Logic of Collective Action—Public

Goods and the Theory of Groups" from 1965 stands out among his famous works. For Olson, the logic of collective action is based on the main idea that when there are common economic interests, individuals will come together to achieve common goals [26] jointly.

In addition, common economic objectives are realised with greater strength and effectiveness through collective action and by promoting members' interests [26]. Collective actions are social interactions driven by collective goals, which generate joint actions to achieve them [35].

For Maeda and Saes [36], the logic of collective action occurs when economic agents, under cooperation, seek to maximise their satisfaction. The gain from collective action must be higher than that of an individual effort. In addition, the authors describe that the success of collective action has other factors, such as the size of the group. According to the authors, small groups present more satisfactory results for members, thanks to the ease of control and agility of actions.

Wenningkamp and Schmidt [24] explain that the interests that Collective Action promotes must be attractive to all members, that is, members should share common interests. Collective actions aim to combine efforts through the joint action of individuals to achieve common goals [24].

According to Olson [26], smaller groups tend to achieve a collective benefit more easily and promote individual interest in the collaborative form. The larger the group, the more likely it is that the individual will reach the optimum goal of obtaining the collective benefit. Furthermore, the less likely he is to act to obtain even a minimal amount of that benefit. In short, the larger the group, the less it will promote its common interests [37].

Thus, smaller groups have more advantages than large groups [26]. According to the author, this is explained by small groups' cohesion and greater efficiency and their social incentives and rational behaviour.

Smaller groups have greater strength of cohesion and efficiency, as individual efforts will influence the final results more so that individuals will contribute more to obtain or improve the benefits. If the group is larger, the strength of cohesion and efficiency of each participant will decrease, and the individual effort or contribution will not have much effect on the larger group [37]. Because of these reasons, Olson reports that large organisations often seek subdivisions within the overarching organisation, creating small leadership groups in the form of committees and subcommittees.

In addition, economic incentives are not the only motivators for collective action. People are also driven by the "desire for prestige, respect, friendship and other social and psychological objectives" [37]. These social incentives also work best in small groups, as people have greater proximity and knowledge between them. This proximity influences the individual to perform his duty or social role in collective action and to value his "friend", social status, personal reputation, and self-esteem. Thus, small groups are favoured in two ways, first by economic incentives and second by social incentives [26].

Maeda and Saes [36] identified similar economic and social incentives characteristics during a Brazilian Rural Collective Action study. Economic incentives include economies of scale, increased bargaining power and dilution risk. As for the social incentives, the desire for prestige, respect, friendship and other social and psychological factors also appeared. It is worth mentioning that the economic incentives prevailed over the social ones in this study. The economic gain with the action is the main factor in maintaining the rural group [36].

Moreover, Olson discusses the famous free-riders, when an individual group is favoured within the structure without contributing to the overall gain. In the study by Maeda and Saes [36], they found that the occurrence of the free-rider is inhibited by the small group size and social incentive. Thus, the social pressure on the small rural group leads all members to comply and participate in actions to achieve collective benefit.

Wenningkamp and Schmidt [38] found economic and social incentives to act collectively and environmental, cultural, and political motivations. For example, we can emphasise waste management and preservation of the environment, power in influencing decisions, commercialisation with the collective model, and recognition and rights in legal/political matters.

Olson [37] briefly describes groups fighting for legislation favourable to their members, specifically for Rural Collective Actions. This is currently the case in Brazil, with large rural organisations, as an example of the strength of the ruralist bench, which has the power to influence politicians in Congress, the Organization of Cooperatives of Brazil (OCB), Brasilia, Brazil, or the National Confederation of Agriculture (CNA), Brasilia, Brazil, which exercise power over Brazilian cooperatives and agribusiness. However, it is not just for this reason that Brazilian Rural Collective Actions fight, motivate or structure themselves.

Iglécias [23] and Ribeiro, Andion and Burigo [20] discuss some historical aspects that influenced these changes. Iglécias [23], in a study on the forms of collective actions and political articulation in Brazilian agribusiness, reports that Brazilian rural collective actions have been transforming since the late 1980s and early 1990s, due to a greater integration of the Brazilian economy with the world economy. Due to this reason, the country became more exposed to international competition, and as a result, farmers strengthened their positions through collective action. Ribeiro, Andion and Burigo [20] state that from the 1980s, structural and socio-political changes began to occur in Brazilian agribusiness due to the re-democratization of the country and the promulgation of the 1988 Federal Constitution. Such changes passed more power to states and municipalities, increasing participation of society in the economy and politics and discussing such issues as social inequalities and preservation of the environment.

Olson's theory approximates the new Brazilian Rural Collective Action model, called the Condominiums of Rural Warehouses. There is a shortage of warehouses for storing grain after harvesting in Brazil. Investments in storage are high and require a high level of financial resources. Farmers, after harvest, sell the harvest at the day's prices so as not to incur losses. It would be possible to store the crop and to sell the produce at a later time. Given the supply risks in substantial crop failures and losses, the lack of grain warehouses is a food security problem. Thus, the Condominiums of Rural warehouse condominiums have emerged as a collective model to solve the problem. However, in collective resources, there is a free-rider problem. We discuss the model of the Rural warehouses condominiums in the following sections.

3. Materials and Methods

We carried out an applied, exploratory, descriptive and qualitative study. Besides conducting a literature review to gather the main variables related to the phenomenon studied, we conducted a case study associated with the Condominiums of Rural Warehouses. We conducted semi-structured interviews with the managers/owners of Condominiums of Rural Warehouses to collect data. We analysed the results through a Categorial Content Analysis under the Theory of Logic of Collective Action by Mancur Olson, also analyzing the results in relation to some studies related to the topic [22,27,28,31].

In related studies, such as a project supported by the Foundation of Support of Research of Distrito Federal—FAP-DF, Brasilia, Brazil [11], the authors did not find any geographic record of the collective action model Condominiums of Rural Warehouses in Brazil. The leading Brazilian associations related to warehouses also were not aware of Condominium of Rural Warehouses, except those existing in Parana and Rio Grande do Sul, Brazil, which were the subject of our study [11]. Thus, the interviews were conducted by considering the representativeness of the existing condominiums obtained by documental analysis, mainly via the Internet and by phone, located in the States of Parana and Rio Grande do Sul, Brazil. The choice of the study participants was made following the criteria of convenience sampling and accessibility. Prior contact was made by telephone, and the best day and time was scheduled, and the interviews were conducted in person. Condominiums of Rural Warehouses are disseminated by people who know the model and some reports are available on the Internet. When we interviewed the managers of the existing condominiums of Rural Warehouses in Parana and Rio Grande do Sul States, Brazil, we asked if they knew of other condominiums.

We carried out seven interviews in loco with the managers/owners of the Condominiums of Rural Warehouses in the municipalities of Palotina (C, E, F and G), Mercedes (B) and Francisco Alves (D) in the State of Paraná, and Ipiranga do Sul (A) in the State of Rio Grande do Sul, in Brazil. There is a greater concentration of this type of Collective Action in these municipalities.

We recognise that the choice of the participants of the study is a limitation of this paper; however, considering the difficulty in Brazil to have responses from questionnaires sent by e-mail [11], the accessibility criteria had proven to be the more adequate in this case, considering the qualitative approach of our study. The results from the project's final report supported by FAP-DF, Brasilia, Brazil, were also considered for the data collection and for accessing the study participants. We analysed the data through the lines and cluster meanings of texts through the categorical content analysis [39]. The questionnaire was derived from the seminal works by Filippi [27] and Olson [26].

Finally, the selection of participants occurred through a pre-selection criterion that inhibited selection and information biases. The interviews were conducted impartially according to the questionnaire, were recorded and the interviewees' testimonies were used to discuss the results.

In this sense, the Content Analysis had three stages: (i) pre-analysis; (ii) exploration of the material; and (iii) treatment, inference and interpretation (Figure 1) [39].

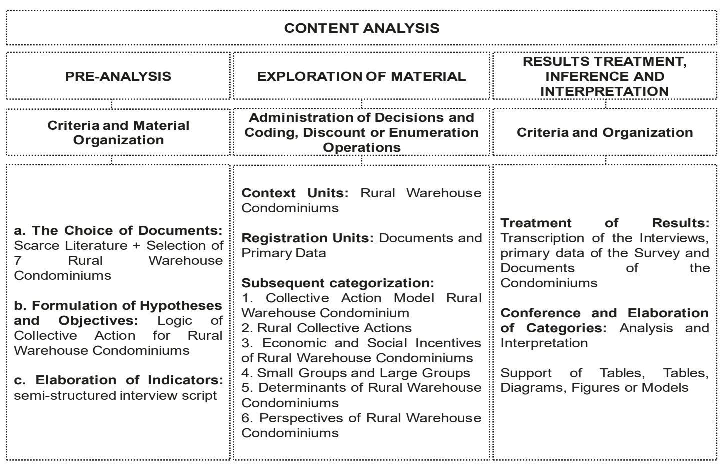

Figure 1. Applied Content Analysis.

Pre-analysis is the material organisation stage, a careful and organisational phase, which aimed: (i) the choice of documents on the topic of Condominiums of Rural Warehouses, for which literature on the subject is restricted; (ii) formulation of hypotheses and objectives, which is based on the Theory of the Logic of Collective Action for Condominium of Rural Warehouses and, (iii) elaboration of indicators and creation of semi-structured interview script to conduct the interviews with managers/owners. The exploration of the material aims to manage decisions through coding, discounting systematically or enumeration operations. In this second phase, the text of the interviews or documents is set into smaller units, with later categorisation. The categorisation is an operation that aims to classify common elements in sets, done before (*a priori*) or after (a posteriori) data collection [39].

The smaller units were the context of Condominiums of Rural Warehouse gathered from documents and primary data obtained with in loco interviews.

This study conducted categorisation after field research (a posteriori), elaborated on after the interviews. The categories proposed are (1) Collective Action Model of Condominiums of Rural Warehouses; (2) Rural Collective Actions; (3) Economic and Social Incentives for Condominiums of Rural Warehouses; (4) Small Groups and Large Groups; (5) Determining Factors of Condominiums of Rural Warehouses; and (6) Perspectives of Condominiums of Rural Warehouses. Finally, the last step was the treatment of the results and the presentation and discussion of the data.

The last stage of content analysis comprised the treatment of results, inference and interpretation of data through qualitative analysis, including the transcription of primary data interviews, analysis of documents provided by condominiums of rural warehouses, and a discussion of the results in light of the theory of Collective Actions.

Moreover, we triangulate data to compare results from different instruments of data collection (interviews, observation, documents and theory) and the opinions of the other managers/owners of the condominiums of rural warehouses. Among the advantages of triangulation is the establishment of truth, improvement of theories, confidence, accuracy, quality, elimination of bias [40] and more robust contributions [41]. We present the results in the following section.

It is noteworthy that there is still no national registry of Condominiums of Rural Warehouses. Thus, the sampling took place for accessibility and convenience. In Brazil, a national registry shows the warehouse units in the territory. Such registration is conducted by the Brazilian government's National Supply Company (CONAB), Brasilia, Brazil. However, CONAB's registration differs between cooperative, private or official warehouse units. There is still no specific survey or classification regarding Condominiums of Rural Warehouses.

We found that the knowledge on Condominiums of Rural Warehouses in Brazil is still insufficient, considering the perceptions of some entities, producers or associations dealing with agribusiness and warehousing. The data from "Project financed by the Foundation of Support to Research in Distrito Federal, Brasilia, Brazil (FAP-DF) carried out between 2017 and 2019 in the Distrito Federal and surroundings corroborated this information. This model of collective action is best known in the Southern Region of Brazil, and more specifically in the city of Palotina, in the State of Paraná. Based on television reports or informal contact, some farmers or entities seek information in the area of Palotina or scientific publications.

In the case of the Brazilian Agriculture Confederation (CNA), Brasilia, Brazil, an entity representing rural producers in the country conducted a meeting to present the Condominiums of Rural Warehouses model, by researchers from universities to 27 representatives of Farmers' Federations in the 1st half of 2019. The representatives were optimistic about the model and became aware of the new Brazilian Rural Collective Action model.

Furthermore, we found that the Ministry of Agriculture, Livestock and Supply of Brazil (MAPA) and the Technical Assistance and Rural Extension Company (EMATER headquarters, located in Brasilia, Distrito Federal, Brazil), were not aware of the topic. It is essential to point out that the Condominiums of Rural Warehouses model is relatively new. There is insufficient knowledge about the country's territorial extension and a poor dissemination of information among producers, entities, researchers, and the government. Thus, the model is better known in the country's Southern Region. From 2016 to 2019, in Palotina, Paraná, Brazil, a further three Condominiums of Rural Warehouses were built, totaling six in Paraná by 2019. Thus, this study considered seven Condominiums of Rural Warehouses known in the country: (a) Warehouse Condominium "A" in the city of Ipiranga do Sul, Rio Grande do Sul; (b) Warehouse Condominium "B" in the city of Mercedes, Paraná; (c) Warehouse Condominium "C", "E", "F" and "G" in the city of Palotina, Paraná; and (d) Warehouse Condominium "D" in the city of Francisco Alves, Paraná.

4. Results and Discussion

4.1. Model of Collective Action Rural Warehouse Condominium

The first category aims to present the collective action model of the Rural Warehouse Condominium.

The collective action of the Rural Warehouse Condominium is an association of farmers that share the same objective, storage. In the specific case, the model aims to store grain production in warehouses, shared among all partnering farmers and divided into storage quotas through internal regulations and a set of rules (statute). In addition, the partner farmers own the unit, which comprises the storage units (Metal Silos) and the administrative building, reception and scale, warehouses (hoppers, cleaning machines, dryer, tipper, furnace, etc.), and another small area available. The whole complex is the Rural Warehouse Condominium in approximately 6 hectares.

Initially, the Condominium assumes that farmers alone cannot make the Warehouse financially viable. Additionally, when they come together collectively, the viability of the Warehouse becomes possible since the costs are shared among all partners.

Olson [26] reports that the formation of groups begins with a common and primary purpose, in this case, the collective storage structure for the Warehouse Condominiums. In addition, the creation of the Condominium corroborates the economic objectives that can be realised with greater strength and effectiveness through collective action.

The model achieves other common goals by collectively making the storage structure viable. Obtaining more significant profit from the sale of the product, minimising costs, adding value to the product, strategic marketing of products, by reducing logistical bottlenecks, rural activity and commercialisation are other incentives for the formation of the collective group Rural Warehouse Condominium, which meet the economic objectives of the Theory of Logic of Collective Action. Table 1 exemplifies some of these statements.

Table 1. Interviewees' statements about the Condominiums of Rural Warehouses model.

Condominium	Description
A	" ... if there is no Rural Condominium, if each producer were to invest in his farm, he would have to invest: in a scale, in a dryer, in a hopper, in an elevator; and finally, in a set of works for one person. A bigger one can even do this, and not like this, as it is in a Condominium, this scale, this elevator, this whole structure that encompasses the Condominium, is in the hands of everyone, each with their share, reducing costs and investment, reducing the labour costs ... "; " ... mainly the cost reduction and then the increase in gain in the final product."
B	"A Condominium is born from a combination of people, needs, goals that converge, after that comes a physical structure that meets those needs, right. Needs that are marketing, you can add value to the product, you sell with a price higher than the market, simply you can sell at a more appropriate time."
C	"I think it is an Association of rural producers with the same objective, seeking better conditions for the purchase, income and storage of their products."
D	"I think it's a model that is easy to deal with. But the initiative was the storage of grains to obtain better profitability in the resale of these products, you know. To be able to add a better value, to reduce the costs in your fields, on your farms."
E	"It is a union of a group of farmers who are going to form the Condominium to facilitate marketing and have a greater gain in their production. Because there is no middleman in these cases, the Condominium sells direct to the end consumer", " ... it depends from year to year but is around 20% more for the condominium. Of course, each year, the spread, when there is a lot of production, the spread is a little lower. But in general, 20%, so the winner is the farmer himself."
F	"How to add value to the final product ... you can reduce costs and increase the value of the final product."
G	"It is a union of people with a defined purpose, and these producers need to have an affinity. There must be a spirit of cooperation within them ... Within the Condominium, the 'me' cannot exist, there must be 'us' to function ... There is the importance of affinity between people, the benefits will be shared", "Yes, it is important to have few producers in the model, up to about 20 owners".

It is worth mentioning that the strategic commercialisation of production is one of the main factors in creating the Rural Warehouse Condominium reported by the interviewees. When marketing their products without the Condominium, farmers reporting having had a reduced profit margin and were often forced to sell the product right after harvest since they did not have places to store their products. Thus, with an ample supply of the product on the market, usually during harvest periods, the prices of the products end up being lower than in the off-season due to supply and demand.

In addition, the price paid to the producer to deliver the product to third-party warehouses is less than that negotiated at the Condominium. The price received for the product through the Condominium is around 11 to 20% higher. In addition, the sale through the Condominium excludes middlemen. The deal is carried out directly with the buyer or trading company, and the profit increases for the farmer.

In addition, respondents noted the importance of the small number of farmers in each Condominium. Each condominium has around 8 to 24 farmers, with an average of 16 farmers for storage condominium and the productive area around 4500 hectares storage capacity revolving around 450,000 bags of 60 kg (27,000 tons).

As in the case of Condominiums of Rural Warehouses, small groups have more satisfactory results due to the ease of control, agility of actions, greater cohesion and greater efficiency, and achieving the collective benefit more quickly. Other aspects such as respect, friendship and characteristics of a social and psychological background are also incentives for collective action and the good functioning of Collective Action [37].

In addition, the existence of a small and restricted group is a determining factor for success for the Rural Warehouse Condominiums model. At the point of deciding to set up the Condominium, the farmers had already known each other, had confidence among themselves, and had similar profiles and ideas that contributed to the smooth running of the model's activities.

In this context, the small group must be well structured and organised, financially stable, and have prior knowledge and/or experiences in collective actions for the model's success.

Another vital characteristic of Condominiums is the profile of the farmers. Small and medium farms prevail in the Condominiums. It is worth explaining that the profile of farmers in Brazil is different, especially when comparing the South region and the Midwest region, the central grain-producing regions in the country.

The small and medium producers in the South region can vary between 100 to 300 hectares. The large farms are over 1000 hectares. In the Midwest region, small farms have at least 1000 hectares. Thus, the Southern region is characterised by farms with small agricultural areas. This characteristic is for forming a Condominium of Rural Warehouses, as a prominent owner of the Midwest region, in economic terms, can easily make his storage viable. However, in the South, this would not be possible.

This fact is reflected in the incentives for making the model viable. Still, it does not exclude other motivations, such as the social and economic ones that the model provides and will be discussed in the third category.

4.2. Rural Collective Actions

The second category reveals perceptions and characteristics regarding the different rural Brazilian collective actions.

Among the different Brazilian rural collective actions, the interviewees know the Associations, Cooperatives and Rural Warehouse Condominiums. As for the Cerealists, the interviewees know. However, it is not considered a rural collective action, as only one owner buys and sells grain.

Respondents also reported the prevalence of large Cooperatives in Palotina/Parana and Rural Associations, Brazil. There are fewer rural condominiums, with around six in Palotina/Parana and one in Ipiranga do Sul/Rio Grande do Sul, Brazil. Associative and cooperative culture is predominant in the country's Southern Region, which creates and develops collective actions.

As for the diversity of agricultural activities in Rural Condominiums, most interviewees know only about the storage segment. Interviewee A reported some form of a Swine Condominium in Salete, state of Rio Grande do Sul, Brazil, but that the Collective Action did not work due to administrative problems, and today it is private. Interviewee B reported knowledge of the Agroenergy Condominium in the municipality of Marechal Rondon, state of Parana, Brazil (Ajuricaba Condominium) and another Agroenergy Condominium that began recently in the municipality of Entre Rios do Oeste, state of Parana. Both transform pig waste into bioenergy through a biogas plant. In the literature, it is possible to notice recent studies with Condominiums of Agroenergy [42,43].

Slightly different from bioenergy production from swine manure, interviewee C reported building a Solar Energy Condominium to reduce the electricity costs of the Warehouse Condominium and supply the rural properties themselves.

In contrast, interviewee F commented on the idea of a Silage Condominium sharing Silage machines, which would reduce investment costs and bring greater efficiency to the production process. On the other hand, Interviewee E reported only hearing about a Milk Condominium in Mangueirinha, Parana, Brazil, which delivers the product to the Cooperative.

In the literature, it is possible to notice a diversity of Rural Condominiums. Noteworthy activities include agroenergy [42,43], logistics (warehouse) [11,22,27,28,31,34], coffee-growing [44], dairy [45–49], and pig farming [47,50,51]. However, studies on the subject are still recent and few.

In addition, among the different rural collective actions, around 80 to 90% of the farmers in the Condominiums of Rural Warehouses participate in other models, such as Credit Cooperatives and Agroindustrial Cooperatives. There are cash loans (financing), purchase of inputs, and sale of products in these relationships.

We noted that rural producers need to associate themselves with collective rural action. Interviewees C and B added: "Now, not associating with anything is bullshit . . . ", "rural collective actions for agribusiness are critical, there should be more", respectively. In the Theory of Logic of Collective Action, collective action is more efficient than disorganised individual action. Thus, the rural activity carried out collectively is more efficient to the processes and objectives of everybody.

Fonseca and Machado-da-Silva [52] and Garrido and Sehnem [4] also corroborate the importance of Collective Actions in competitive and fierce business environments to face competitive scenarios and the survival of institutions strategically.

For Saes [25], collective action achieves the individual interests of each person. The objectives are more easily achieved, and the associates' profit is maximised, goods or services are provided, the "rules of the game" are changed, and conflicts are resolved.

Thus, the interviewees' unanimously asserted the importance of collective rural actions for agribusiness and the whole production chain. We can highlight the security, aggregation of value to the product, generation of jobs, dilution of costs, a gain of scale, quality of food, marketing increase in profit and use of technologies as main advantages.

With this, interviewee E commented on the importance of farmers staying together because rural collective actions cannot be achieved if there is no union. Likewise, interviewee G said that soon he sees the formation of an Association between Condominiums of Rural Warehouses to ensure greater representativeness of the category and seek better financing conditions, such as lower interest rates, as different needs may arise.

In addition, for the rural producers of the Condominiums, the viability of the storage structure and the extra profit obtained from direct sales and strategic marketing were only possible thanks to the cooperative union of producers. "I was always very accountable and was not viable alone. I was going to have a high maintenance cost to play alone, and in this collective way, I think it went well" (interviewee B); " . . . what changes are for the groups that make it up, who manage to have a slightly higher final gain in his currency, which is the grain" (interviewee A).

The "surplus" with the sale of the products (grains) directly to the market, without intermediaries in the transaction, and the possibility to sell the product at any time of the year, especially in the off-season when the price of the product is best, are the main benefits. This condition is possible considering the Condominium's capacity of storage.

In addition, the rural collective action models differ from each other. The Condominiums of Rural Warehouses differ from the other collective actions because it is driven to a smaller, non-business group, with a limited warehouse share, and less bureaucratic. Table 2 summarises the advantages of the Rural Warehouse Condominium model over other rural models.

Table 2. Interviewees' statements about the advantages of the collective rural model of Condominiums of Rural Warehouses compared to other types.

Condominium	Description
A	"The advantage I see is that the security of managing our product, which takes place within our farms, and you will sell to the available price, with the highest price and managing to make sales."; " ... at the Condominium, as we always had the standard grain, we delivered the grain clean, dry, without impurity or moisture problem."; " ... mainly in the fiscal part that you do not have any type of tax, besides FUNRURAL. In other collective actions and Cerealists there is PIS, Cofins, etc.".
B	" ... the main thing is this 'plus' that you gain the most in the product and the decision power that you perceive, the partner has power. I am employed here, but you are going to another class action ... at a bank, at meetings, and so on, they end up inhibiting the guy in his corner. In the condominium, the producer has decision-making power ... the main advantage is this, financial, decision-making power, agility in decisions."; " ... the bargaining power remains with the farmer, you know. The sales decision power ... the partner owns the physical part of the grain. But you have the grain in your warehouse. I think there is more bureaucracy than another system".
C	" ... as a group, it gets better prices. It manages to close a larger volume, more competitive in the market than in other collective groups "; " ... I think the best thing is the price, storage, product quality, to delivery logistics, line of delivery. We know how to manage this well, there is no queue here ... outside there is a 3-day queue".
D	"It has advantages: adding value to the product sold, to the final product. Lower costs for the producer, logistics are better, right?"; " ... what we perceive is in terms of quality". "So one of the differentials of the Condominiums that we hear about is this quality of grain".
E	"The advantage it has is the ease in commercialisation, of gain for the producer, it certainly has an advantage, financial gain, and financial gain in the purchase of inputs."; "This is different from the fast delivery, agility from farm to the warehouse, which faces no queues to deliver their products."
F	"As it is a smaller group, it will work more focused, it will be less branched and this will make it easier to achieve the goals".
G	"The big difference is in management and operating costs. Rural Warehouse Condominiums are more competitive in terms of cost. The sale margin is better for the Condominium than for other collective actions. Depending on the time of year, you can get 17% more in corn and 11% in soy. In addition, the Condominium is more agile, quick responses, decisions".

In addition, the difference between the Condominiums of Rural Warehouses and other Brazilian Rural Collective Actions is that the farmer owns his grains, since the warehouse is his and he can choose the best time to sell his product and product quality. Complementarily, the participants of condominiums of rural warehouses have greater decision-making power in meetings. Concerning their product, they also have the autonomy to decide when it will be sold and to whom, that is, they can negotiate better prices for it, as opposed to selling at over-the-counter prices offered in other rural collective actions without negotiation.

Decisions and management in smaller collective action models are also faster and more agile, as in Warehouse Condominiums. There are tax advantages over other models, as they are not companies; condominiums do not receive discounts.

Concerning the problems of agro-industrial logistics, such as deficits in warehouses and queues for loading and unloading, the Condominiums of Rural Warehouses avoid these problems. Considering that there are few partners in the Condominium, the flow of loading and unloading in the silos does not generate queues. In addition, each partner has their share of storage, so each producer knows the space available to store their products in the Condominium silos. Suppose space is lacking, depending on the crop years or increases in production. Farmers can use the quota of another partner. When the managers/owners of the Condominium decide it is possible to expand the storage capacity they can construct new silos.

4.3. Economic and Social Incentives for Rural Warehouse Condominiums

The third category discusses the role of Economic Incentives and Social Incentives in front of Rural Warehouse Condominiums, motivating bases for forming groups according to the Theory of Logic of Collective Action.

First, respondents almost unanimously agreed about Economic Incentives relating interest rates to warehouse financing (Table 3). When asked about the role of Economic Incentives in forming groups, we discussed two relations: Governmental economic incentives and market-based economic incentives.

Table 3. Interviewees' statements about the Economic Incentives of the rural collective model Condominiums of Rural Warehouses.

Condominium	Description
A	"The member farmers already knew that they would have a greater profit with the Condominium. But they didn't know how much. Today they know how much they pay the freight, the award of the port, the Chicago value; this information came with the Condominium, and you access it via the internet, the prices given in the main markets, you know. The manager always sells on FOB; they do not pay the freight."
B	"I don't see a specific incentive, from the government to groups. I don't feel that, for example, I'm going to make a bigger profit with Condominium; that was an incentive, for example."
C	"Today, interest has doubled; it has become more expensive. It scares a little, you know. So if you look, the reality of the business is that interest is costly for this type of investment. So much so that the company KW came here and said that they did not do any new works in the last year; the last one was in 2017. Today is a good deal, but you know it will be extensive today, with interest. And the equipment prices went up a lot, the higher price for the bag is a good incentive, but due to the interest, everything will be on the way, and today you will join capital and pay, forget it, this will not. It is long-term financing. I still think there should be a credit line for this producer for this model. The problem is high-interest rates."
D	"There is little evidence that the economic incentives for this side are still small. But I think the government should see this issue of interest rates for this side of agribusiness; one thing is, in that sense, right. Try a different interest rate for smallholders."
E	"When I was not here, but when the expansions, in the beginning, had become difficult to acquire cash to mount the Condominium and other companies simply spoke, "No, it will not work." So I think it is clear that today we realise that banks encourage and have a higher turnover, we say. Within the municipality, the farmer himself will practically generate more money. When the construction was done here, we had some problems with interest rates, and if the last financing, we took more time to pay and a rate of 4 or 4.5% per year. Facilitated right? So, if there were incentives like these and a greater union of producers, surely there would be more Condominiums."
F	"Reduced costs in the Condominium and increased profitability, resulting in a higher profit margin in the sale and commercialisation in the final result. The lower interest rate at the inauguration; today, the interest rate has increased. However, the country still has a storage deficit, and there is a need for the government to encourage investment in storage to supply the deficiency."
G	"The first Condominiums 2012/13, the interest rate was low. Even today, it has risen a little. However, it went up. There is no subsidy. The main differential, economic incentive, would be the spread, which the Condominium gains from the sale; the farmer owns the grain".

The governmental economic incentive applies because the Government restricts contributions with financial incentives to the collective action model of Condominiums of Rural

Warehouses. Mainly to incentive programs for the construction or expansion of Warehouses with competitive interest rates for small and medium rural producers.

Currently, the central government program available for Warehouses is the PCA—Program for the Construction and Expansion of Warehouses—with interest rates ranging from 6% to 7% per year, 6% for investments with a grain storage capacity of up to 6000 tons and 7% above that [53]. According to the interviewees, interest rates for farmers are high. They have risen over the last decade, mainly for small and medium farms, being a disincentive for structuring new Warehouse Condominiums and new construction of storage units in the country.

It is worth remembering that there is a storage deficit in the country and obsolete storage units that need modernisation. At a more favourable time, the lack of warehouse spaces still implies not enjoying storage benefits, such as product conservation and commercialisation.

In addition, we asked the interviewees about the non-knowledge about the model of Condominiums of Rural Warehouses by the Government. So, we perceive a need for greater articulation between governmental economic and social agents to learn about the country's reality and outline economic and social incentives for this emerging Brazilian rural collective action model. This articulation is essential given the model's contribution to reducing the warehouse deficit, greater product competitiveness, regional growth and development for agribusiness and municipalities, and money turnover in the country's economy.

In addition, on the economic incentives of a market order, the extra profit that rural producers have when marketing production with the Rural Warehouse Condominium is exemplified: "The main differential, economic incentive, would be the spread, which the Condominium gains with selling the grains owned by farmers" (Interviewee G).

This characteristic shows the extra gain with the owner's product when selling his production through the Condominium, without an intermediary in operation. Even stored, the producers keep the property of the produce (grains) because the participants own the silos. This gain can vary between 11 to 20% more per grain bag, depending on the time of year.

It was also verified that Government economic incentives are unattractive and insufficient for the country's construction and development of Condominiums of Rural Warehouses. However, concerning market economic incentives, mainly about the extra gain with the product in strategic marketing, there are favourable scenarios for Rural Collective Action, solid determinants for the rural model.

In the Theory of Logic of Collective Action, economic incentives are paramount for forming groups. If there are no economic incentives, a group does not survive long term, and there is no reason for the activity to remain in the market. Thus, producers' additional gain in marketing the product through the Condominium is a condition for the organisation to survive and promote its members' interests. However, high-interest rates for the financing of condominium warehouses have hindered the rural model.

Maeda and Saes [36] consider that Economic Incentives are superior to Social Incentives. Thus, the economic gain from the rural activity is a fundamental condition for the group to survive in the market.

Economic Incentives are not the only determinants for forming groups under the Theory of Logic of Collective Action. There are also Social Incentives, such as prestige, respect, friendship and social and psychological characteristics that encourage people to organise themselves into groups. These characteristics are evident in the collective actions of the Rural Warehouse Condominiums. Table 4 illustrates the social incentive.

Table 4. Interviewees' statements about the Social Incentives of the rural collective model Condominiums of Rural Warehouses.

Condominium	Description
A	"I think it would be interesting, but it's missing. We had a lot of politics; this one is more difficult. We noticed that the formation of our group lacked a lot of incentive on the part of the government, mainly the city hall, which is something more local, municipal incentive."
B	" . . . after the formation of the Condominium, there are always these conversations, exchange of ideas between farmers, it is the conversion of grains, it is a cry for the weather, but I think that was not what encouraged the group's formation. It happened later, but it was not a start; it was more about adding value, having the storage structure itself. After the Condominium, some owners have more contact with each other; they used to see each other in the city, but today there is more interaction between them."
C	"Contact with producers, exchange of learning, the relationship between those who participate in the condominium, all staff, residents and those who work here, this is excellent. This gain, this interactivity, the conversations with people, have more gain."
D	" . . . the farmers come here every month, we do accountability, like right, contracts, storage, if we are going to do something new, right. There are exchanges of information, between them and me, viability spreadsheets, whether they are going to buy or not, of the legal aspects."
E	"At meetings, we exchange many ideas between managers; this is very good."
F	"There is technical growth, professional exchange in groups. For example, in Cascavel, PR, there are several warehouses for families; there were a couple of producers who had warehouses on the property. Still, it was not worth the costs".
G	"Within the social sector is jobs, exchanging information between farmers. They talk a lot about the experience (input, seed)."

Social incentives were highlighted by the interviewees, including greater interpersonal relationships; exchange of knowledge, information; technical and professional growth; job creation; learning among the Condominium's professionals and farmers, etc. Note the diversity of social incentives generated with the Condominiums of Rural Warehouses, which strengthen the rural movement and benefit from the interaction between all model members.

The Logic of Collective Action describes the "social pressure" in-group behaviour with Social Incentives. There is a set of rules in Condominiums of Rural Warehouses Condominiums, which is the model's Statute. The farmers' efforts and the model follow the Statute. In addition, each producer and/or employee is willing to help and collaborate with whatever is needed in the Condominium of which he is part. The demands are not binding, but rather, because the rural producers own this model and know each other, everyone collaborates in meeting the needs that may arise.

In addition, at Condominium meetings, everyone freely expresses their ideas, respects themselves and actively participates in the model. Interviewee A also reports that the rules and responsibilities are more "easily enforceable" in the smaller group, the Condominium.

For Olson, "social pressure" makes it easier to fulfil individual obligations in smaller groups due to the appreciation of the company of friends and colleagues and the zeal for social status, social prestige and self-esteem. The author reports that the social incentives and "social pressure" only work in small groups so that each member has "face to face contact with all others" [37]. In this sense, Social Incentives favour Condominiums in smaller groups.

4.4. Small Groups and Large Groups

The fourth category analyses the characteristics of rural collective actions between small and large groups. According to the Collective Action Logic Theory, smaller groups have more advantages over larger groups, smaller groups are more efficient and effective, and social incentives work better in small groups. Table 5 delineates the main aspects regarding the rural collective action model of Condominiums of Rural Warehouses, notably a small group.

Table 5. Interviewees' statements about the perspectives of the rural collective model Condominiums of Rural Warehouses in Brazil.

Condominium	Description
A	"I think it cannot be too big or too small. Because if it is too small, it will not pay back to maintain itself, cost, firewood, employees, accountant, maintenance, we notice that each year it increases more. So it cannot be minimal, and the very large, the producer already places the silo on the property already has the capacity. Then an intermediate group. There would no longer be that social one in a large group, which everyone is friends with. In a larger group, with 100, 200 associates would have queues of trucks in the yard and cannot inspect all accounting movements. Here, we are 20 or so, we have more agility in unloading, faster, etc. Unity is strength . . . the small group is more united. Besides, it is an individual action that is more recognised in a small group." I believe that the small group has more advantages because it is more controlled, the general movement of grains, the financial movement, is more controlled. Smaller groups more easily achieve collective benefit by being more reliable, organised, and accessible. Communication becomes easier . . . in a small group, I can better communicate the events of the market."
B	"Because there are fewer people, fewer heads, more occasional opinions, there will undoubtedly be fewer differences, but it is easy to reach consensus. Advantages of small groups are agility in decisions and a common goal . . . so the group becomes more homogeneous, more confident. Due to the speed of decisions, the most significant advantage is small groups. A disadvantage is that we lack a minor scale, the area is small, 2000 hectares, but it is our region's profile." . . . Decisions are faster, it is easier to reach consensus in the group. It is easier to demonstrate the numbers, advantages, situations at the meeting, in a large group, for example, sometimes I wouldn't even question it for fear of looking silly."
C	" . . . because you are small, you choose the guys who are most similar to you, the way you work . . . when you get a lot of people, you have many different opinions. When you make a group, you have to know how to choose people well and have the same goals, not thinking much differently. . . . is more affinity with each other, has the same goal. It doesn't diversify that much; it works more focused on the same purpose. The more people, the more ideas begin to diverge a lot. Then it becomes more challenging to manage. Everyone here understands that improving the Condominium is improving the situation for yourself. Smaller groups also get reasonable prices to bargain by joining."
D	"A Condominium with a leaner society would be better to work than with a Condominium with more people . . . if there are a lot of people, each one has their opinion, so we have to get it, get all the views and try to find one better consensus to make it suitable for everyone. But if there are fewer people, everyone is going the same way. Here, he treats it as if it were his right. Advantages do have the issue of price, seeking to reduce costs and add profitability. But also of the capital invested here, right? The condominium producer has to deliver 100% of his productivity here in the Condominium. So I think this is a collective work, the efforts that each one has to make."
E	"I think the release of credit for small groups is not easier, but it depends, right? Everything has to have its guarantee. Indeed, rural collective actions work best with small groups. Because in larger groups, they are "owners" in quotes, but the company handles everything . . . the producer doesn't say anything there. He has to do what the company proposes. Here at the Condominium, "I want a price x of the product, within the clear market", he will get it. So with small groups like this, it is much easier to do it. The Condominiums have financial gain in favour of you, and in large companies, the company wins. . . . most of them hold meetings, and most of them get there, "let's do this, let's do that, let's expand", so there is a union to do it, to build something more for the benefit of themselves. Smaller groups are easier because it is easier to get together, pick up and reach consensus to purchase everything, inputs, product sales."
F	"It is easier to manage in smaller groups, to organise, to be transparent. Condominiums have more advantages than larger groups due to logistics, product quality, adding value to the final product, the comfort of the producer delivering the product; the producer's safety is the owner of the product (the Condominium is an extension of his farm). Everyone participates; it is the individual efforts of everyone here in the Condominium; the farmers themselves act in the administration." "It is easier to manage, more transparent of smaller groups, less bureaucracy."
G	"Small groups are more likely to succeed, to work, to prosper. The advantage of the Condominium is that the spread margin remains for the producer. In the other models, the spread is for the trader. Decisions are faster; operating costs are lower, a competitive advantage. The individual efforts are proportional among all; it is divided among all the farmers, so everyone participates."

It is possible to notice characteristics that distinguish small and large groups and that stand out in small groups. Small groups are treated in this study as groups of up to 25 people (production around 4500 hectares, that is, 315,000 bags of 60 kg, with 70 bags yield per hectare on average). Large groups would already have 100 and 200 members (around 2.5 million bags of 60 kg).

This distinction is considerable for the development of Rural Warehouse Condominiums since this condition implies the efficiency of the progress of all Collective Action activities, including the financial return to maintain the model itself. According to interviewee A, a Condominium of Rural Warehouses can be small or large. Since it is tiny, and has low production it would be unfeasible to pay for the entire structure of the Condominium, which includes expenses such as energy, employees, maintenance, etc. On the other hand, a large producer could have its storage structure on his farm. In this way, he would make the installation costs viable individually. It is worth remembering that the Condominium model brings other advantages, not only the feasibility of own storage.

The small group still presents the advantage of the social characteristic for all members, a strong point described in all statements and meets the Theory of Logic of Collective Action regarding Social Incentives. Smaller groups achieve collective benefit more easily than larger groups; Social Incentives work best in small groups. Since the smaller the group, this fact occurs, the easier it is to reach the optimum point of getting the collective benefit. That is why larger organisations form small groups, smaller subdivisions [26].

According to the testimonies, a group with fewer people has fewer different opinions. Thus, it is easier to reach a consensus, and more occasional disagreements will arise.

In addition, small group participants start from the same common goal more simply. This aspect is more satisfactory in smaller groups. Smaller groups are more easily controlled, people know each other better, organisation and communication are easier, and the small group is more united and of greater affinity.

Other advantages prevail in small groups, such as in Warehouse Condominiums. The main benefits of the model are as follows: greater agility in decisions, speed in unloading and absence of queues at the silo, higher profit margin (product quality and direct sales), better prices and conditions in the purchase of inputs, express their opinions in the group for being smaller, logistical proximity to storage with ownership, and being the "owner of your product" provide freedom in marketing.

Individual action is also better recognised in smaller groups. In the Theory of Logic of Collective Action, this occurs since, in large groups, the typical participant knows that their efforts will not influence the result too much. He will be affected in the same way by the final decisions. Thus, individual effort in larger groups will not influence the decision. In smaller groups, the personal effort reflects more on the final decision.

Another fact identified in the collective rural models was the market competition between small and large groups. Even before the existence of Rural Condominiums in the region, large groups prevailed, which held 100% of the sales and associates. With smaller groups in the area that are similarly competitive or more, there is more competition among the different associative forms. This fact is positive for the end customer since, in more competitive markets, groups must always seek their best quality products and strive to be a more efficient and effective organisation. Otherwise, the client or associate will look elsewhere for these qualities.

Furthermore, for small groups, access to rural credit and bargaining power may be more challenging to achieve. Financing requires guarantees from the rural producers. Therefore, they must come together to fulfil this criterion needed for the banks to finance the storage structure. High-interest rates aside for small producers. Together, to gain more bargaining power and scale, smaller producers must come to achieve these goals. In larger groups, such aspects are more easily achieved.

Finally, it is possible to highlight the main differences between small and large groups according to the Rural Collective Action of Rural Warehouses Condominiums and the Theory of Logic of Collective Action (Figure 2).

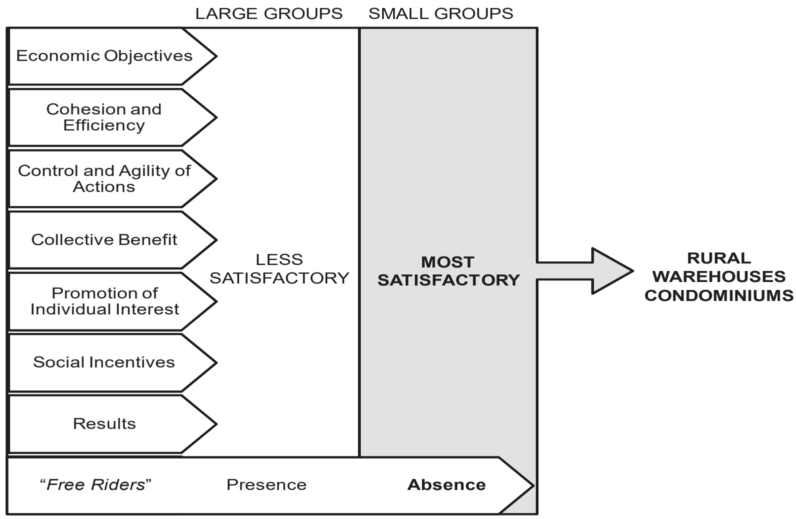

Figure 2. Differences between Small Groups and Large Groups.

Based on the results, we verified that in small groups, such as the ones forming Condominiums of Rural Warehouses, the economic and social objectives, the control and agility of actions, the promotion of individual interests, cohesion and efficiency, and the results are more satisfactory than in large groups. Additionally, it is noteworthy that there are no free-riders in small groups, since everyone participates actively, knows each other and are driven by friendly relationships alongside Social Incentives, which are more easily attainable in smaller Collective Actions.

Finally, for a small group to be successful compared to larger groups, it must be well structured, organised, and financially supported. In the case of Condominiums of Rural Warehouse, the rural partner producers already belonged and/or knew models of collective actions, such as Cooperatives and other types of Associations. In this way, they already had practical and prior knowledge about collective effort to make the collective action Condominium of Rural Warehouse model works correctly.

4.5. Determining Factors of Rural Warehouse Condominiums

The fifth category qualitatively discusses the main determining factors for Condominiums of Rural Warehouses.

Some factors repeated the testimonies of charges and went against Economic Incentives and social conditions for forming groups. The advantages with the product commercialization, direct sales and superior profitability—the added value, the logistical gains, no queues, less flow and proximity of the storage unit to the rural property—and the social gains from the model of collective action are decisive benefits for Rural Warehouse Condominiums. Figure 3 presents the significant economic, social and logistics determinants for forming the condominiums of rural warehouses.

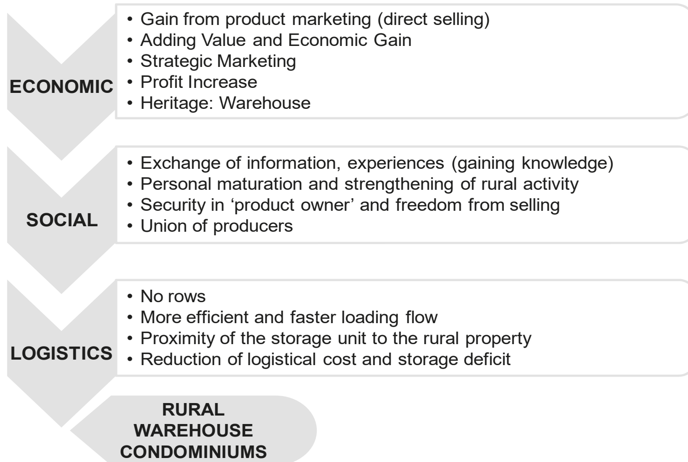

Figure 3. Determinants of Rural Warehouse Condominiums.

In the economic determinant group, one of the main motivating characteristics for structuring rural collective action is illustrated, which is the economic gain with such activity. This characteristic is remarkable for forming groups according to the Logic of Collective Action. Having its warehouse structure, understood as an extension of rural property, allows the rural producer to sell his products directly, without intermediaries in commercialisation, and at a reasonable time for him, causing an increase in his profit and adding value to the product, through the collective model and the best quality of the grain. It is worth remembering that the warehouse also belongs to the rural producer, which means that it is his property. This characteristic differentiates the Condominiums from other Brazilian Rural Collective Actions. Additionally, it guarantees the power of negotiation of the producers and dilution of costs between all partners.

We obtained these characteristics through the following main motivating economic factors highlighted by the interviewees: "security of having your product in your warehouse", "adding value", "storing and selling the product", "economic gain", "increased profitability" and "product commercialisation" (Table 6).

As social determinants for the structuring and development of Rural Warehouse Condominiums, the main factor is the importance of unity among producers. This characteristic is a condition for the creation and development of Condominiums. All producers act as partners with each other, have good relationships and share the same ideas. Common goals are essential for the business to be entirely successful.

Along with these social aspects, the rural producers belonging to the Condominium gain from exchanging information and experiences, thereby generating knowledge. Throughout such activities, producers still enjoy personal maturity and strengthen rural activity, which also leads to advantages in local growth and development. Again, Olson [26] describes that social incentives are more easily achieved and work better in small groups, as with Condominiums.

Finally, as to the logistical determinants, the Rural Warehouse Condominiums circumvented some logistical bottlenecks faced by rural producers, such as queues at third-party storage units, mainly in peak seasons. Thus, the model provides better efficiency in the loading and unloading flow and reduces the storage and logistics deficit.

Table 6. Motivating Factors for Condominiums of Rural Warehouses.

Condominium	Description
A	"Their objective at the time, 1st was security, that you have your product stored, even though it is a Condominium, it is an extension of your farm, so you have grain security on your farm and 2nd add value to the product. And the 3rd today, which I say, is the ease of delivery, the reduction in the time you leave the field with the truck, get here, and you don't have that queue with all those people who deliver, here are just the partners, so decreases many flows, decreases a lot in queues. Time gain, money gain, security of the structure. And the 4th item that I see on staff today is their personal maturity."
B	"The main factor is adding value to the grains. It's not the main thing, but as I put it before, the logistics factor ends up improving, for example, standing in line, right. It comes together to add value. And, for example, when you deliver to a third-party warehouse, your grain is no longer yours. Here, the owner, the physical part if he wants to remove it from here a few days he has this power, you know. The question of you being the owner of the grain yet. In addition, the bag of soy is sold around 6 to 8% more than in the local market."
C	"Aaah has many. For example, in another Rural Organization, more significant than the Condominium and third parties, she imposes the rules on you, you have to follow her rules, she has all sectors, HR, financial, administrative, etc., everyone who works there has to receive, right, it has a much higher cost, right? For example, most people who help organise the Condominium do not receive anything because they are the owners, so we have as few people as possible to work. So the main motivating reason for the Condominium would be the storage and sale of the product ... You have the product in your possession; you can have a different price. If you delivered the product to a third party, it is that over-the-counter price, the product is no longer yours. They also have Social Incentives, you exchange ideas with people here, about a problem that may be yours today, exchange of knowledge helps to have a better view of what to do you know. When you are alone, you can talk to anyone on the street, but sometimes they don't have the same knowledge as the people who are here inside the Condominium."
D	"I think that one of the main factors here is the Union of people, the knowledge among them. And what each one wants, if each one wants to pull to the same side, because we see that here and I think the same in the other Condominiums is that everyone is always thinking the same way. The focus is not the same if one pulls to one side and the other. So, the 1st motivating factor for the Union. And here, another factor that led them to do this here was to sell their product when they want ... So another factor that they take is the question of being able to hold this product, right, for a longer period and sell at a better opportunity. This factor is also one mentioned. And it ends up making a bigger profit. Other factors that could also be, a matter of logistics, because the producer comes here, unloads, it's just him; there is no queue, and the flow is less."
E	" ... delivery is agile, better prices, better prices for sure. Economic gain for him better right. And faster. Of course, you will receive it if you deliver to a third party, but here at the Condominium, it is direct, without intermediaries. So the main factor would be the financial part; it would be that extra gain that he would have. They realise that today, those who take this 20% are the intermediaries, and there is no such thing here in the Condominium.If there is, for example, a group, as long as it works together, there is greater agility in all sectors, in receiving and shipping these products, you know. And a primordial thing would be in the purchase of inputs, which then, they also have a gain in the purchase, that they will get the product, the product that will acquire the seed, the input, with a lower value."
F	"The main factor is the increase in profitability. Other factors would be logistical convenience (close to the property, without a queue), and the product is still yours."
G	"The main factor is the commercialisation of the product, the producer who sells the physical product; it is his, he still owns the grain. The 2nd incentive factor is the agility in the delivery of the production. And the 3rd the product standardisation, higher quality."

4.6. Perspectives of Rural Warehouse Condominiums

The sixth and final category comprised the rural collective action model Rural Warehouse Condominium in Brazil.

The knowledge of the Condominiums of Rural Warehouses is restricted to the South of the country, mainly in the region of Palotina in the state of Parana, Brazil. Even the Condominium managers are unaware of other Warehouse Condominiums in other cities or areas of the country, including the Ipiranga Condominium and the Condominiums in the Palotina region, which are not known.

However, there are favourable scenarios for implementing new Rural Warehouse Condominiums, mainly for small and medium producers and places where there are logistical bottlenecks and storage deficits. This would be useful for rural producers who aim to enjoy the advantages of the condominium model, such as storage itself.

The interviewees provide some critical characteristics for the success of collective action of Condominiums of Rural Warehouses and for them to develop in other regions, such as (i) profile of the rural producer, producers who are unable to make their storage structure viable, or who seek be in some Rural Collective Action; (ii) regions with an associative culture and/or places where cooperatives or rural collective actions already exist; (iii) the group must have confidence and an entrepreneurial spirit; (iv) all farmers will be responsible for the smooth running of the model; (v) have a neutral, reliable figure with knowledge in agribusiness and marketing to manage and sell the products of the farmers (Condominium manager); and (vi) ascertain the production and storage needs of each partner before setting up the Condominium. Table 7 summarises some excerpts from the interviewees' statements on these aspects.

Table 7. Interviewees' statements about the perspectives of the rural collective model Rural Warehouse Condominium in Brazil.

Condominium	Description
A	"If taking the Midwest region is a region of larger producers, then I don't know if it is feasible for you to join. I think that everyone there already has their capacity. Now, taking the South region, Santa Catarina State, I even believe it is viable, Parana, it just depends on selecting a group where you have confidence and entrepreneurship. Because it cannot be a group where one pushes forward, everyone has to get along."; "It is important to have a neutral figure in the Condominium, even that was the question of my being selected, of not being related to any of the 24 members and knowing my family's nature"; "But I think there is a lot of Condominium in the South region, in SC, mainly in the west of SC, there are more micro-producing regions . . . Xanxeré, I worked there for a while, I see that it is very similar to here."
B	"No, I am not aware of other places, outside the west of Paraná, this model at first I thought we were exclusive in Brazil." (laughs) "And the visits here at the Condominium are local, some farmers from Toledo came to visit us here. Nova Santa Rosa, close by. Know the model".
C	"I think it works anywhere. But it depends on people's minds, right."; " . . . ours here has adapted to our region here. Perhaps if you are going to ride there in Mato Grosso, you have to see the amount of area, but it works anywhere."
D	"We see our neighbours here, regions like ours, and people don't get together to build this here. So I do not know why this model works here, and there does not work or do not see. Why here in addition to our Condominiums, we see more, 1, 2, 3 . . . 3 to 4 Condominiums considering doing here in our region."
E	"Today, we know that there is a lack of storage in the country, and I think that maybe there is a little lack of union among farmers. Without their union, if everyone thinks for themselves, they will never build a Condominium. So if there is a Condominium that is working properly, then people should rethink it, since there is a lack of warehouses in the country."
F	"They have been working well here in the Palotina region and have been growing."
G	"It would be very viable in remote regions, the need to unite producers when you can share the cost among some producers; the benefits will also be shared. A new one will also come out in Terra Roxa. It is important to have few producers in the model, up to about 20."

In turn, the Condominiums of Rural Warehouse model is more sought after by people from the regions of origin of the Condominiums. Still, there are also interested parties from other areas of the country. The target audience is usually made up of farmers who have heard of the model, are looking to visit the existing Condominiums of Rural Warehouses to understand how it works, and to assess its viability.

Interviewee C reported interest and visits from different persons to learn about the model, from farmers, people from other states, and companies that sell silos. Interviewee D also reported the disclosure of Condominiums by companies that sell silos and reported having been visited by students from the Federal University of Paraná (UFPR), Parana, Brazil so that they could learn about electrical specificities as students of Electrical Engineering and agricultural colleges in the region, acting as temporary interns.

Complementarily, there was an expansion of this rural collective action in other municipalities in the South region. The interviewees are aware of new Condominiums of Rural Warehouses under construction. Some of them are in the vicinity of Marechal Cândido Rondon (Parana, Brazil) and Não-Me-Toque (Rio Grande do Sul, Brazil), and in the municipalities of Nova Santa Rosa (Parana, Brazil), Terra Roxa (Parana, Brazil) and Sapezal (Mato Grosso, Brazil). However, other states have already sought information, such as Minas Gerais and Mato Grosso do Sul. The interviewees cannot say whether Warehouse Condominiums have been established in these locations.

Furthermore, regarding the long-term success of the model, it is crucial to define the set of condominium rules (by laws), the issue of leaving members or family succession/death of a partner. It was noted that the topic could generate conflict between partners if it is not managed in a transparent and equal way among all. Thus, it is vital to set clear rules regarding whether the Condominium allows the sale of the storage quota, its valuation and who has the privilege of buying, for example, if another partner can purchase the quota or if external member of society can.

Finally, Government economic incentives become motivators for the creation and development of Condominiums of Rural Warehouses, mainly via financing programs for storage, which is in line with the profile of the rural producer and compatible interest rates. Together, the profile of the rural producer is consistent with the model, since smaller rural producers who are unable to access a storage structure are eligible to become part of the Rural Warehouse Condominium model and can enjoy the other advantages that the collective action brings.

As a dimension of the rural model Condominiums of Rural Warehouses, we suggest that collective action should meet the productivity needs and static storage capacity of partner producers, should have the capability to expand and should be financially viable for all members.

Considering the perspectives of the managers/owners of Condominiums of Rural Warehouses and some findings of this study, we identified the owners' demands and perspectives with other types of Rural Condominiums. Some examples include the Energy Condominiums to reduce energy costs from a sustainability perspective; the Silage Condominiums share machines and generate greater efficiency and reduce costs. Both models do not yet exist. Only Agroenergy Condominiums transform animal waste into bioenergy; thus, we suggest technical and financial feasibility studies on the topics.

5. Condominiums of Rural Warehouse under the Lens of the Theory of Logic of Collective Action: A Reflection Based on Content Analysis

The Logic of Collective Action theory clearly shows that collective action can arise at the moment that a number of individuals have common economic objectives. This argument is clear to the Rural Warehouse Condominiums.

The small group of rural producers with common economic objectives is present through storage in the rural collective action model. Rural producers, with the objective of establishing warehouse structures, taking advantage of the condominium system and storage, and circumventing logistical bottlenecks led to the creation of rural collective action in Brazilian agribusiness through the sharing of storage quotas.

The model is suitable for a small group, of between 8 and 24 rural producers, who produce in an area of 4557.14 hectares on average, and capable of generating revenue through the sale of production and storage. Thus, there is a financial and economic condition to make the storage structure viable and maintain the Condominium costs over the long term.

In addition, the producers who belong to the Condominium already had experience and/or knowledge in other forms of collective actions, and many farmers were already part of different types of cooperative models. However, the Condominiums of Rural Warehouse differ from other models by making the warehouse structure a common asset for all rural partner producers. Besides that, promoting the strategic commercialisation of production, direct sales of the products (grains), superior profit from the sale, its characteristic as a less bureaucratic model, greater decision-making power over their product, reduced queues in the loading/unloading of the warehouse and enter the unit. The producers own the storage structure itself, and individually. The warehouses would not be viable for small and medium producers outside the model.

In this context, small, restricted and closed groups, as in the Condominiums of Rural Warehouses, is a determining factor for the success of collective actions. Relationships of trust and friendship between the partners, with similar profiles and ideas, contributed to the smooth running of the model's decisions and activities. Small groups of rural grain producers organising themselves in Condominiums of Rural Warehouses are more likely to overcome their latency when realising that the benefits of cooperation outweigh the costs of achieving the physical storage structure. In this way, everyone assumes the cost of providing the collective warehouse.

Notably, the structure, good organisation and transparency, together with a neutral figure to manage the model, and financial and economic conditions, promote Condominiums of Rural Warehouses' longevity and growth and competition in Brazilian agribusiness.

It is worth noting that the country's political and economic conditions can encourage the structuring and expansion of this model. However, particularities related to each region should be considered. Government incentives, such as interest rates, rural credit and financing programs for the warehouse and the profile of small and medium-sized rural producers, are incentives for the viability of Condominiums of Rural Warehouses.

With the Collective Action Logic Theory, Condominiums of Rural Warehouses, formed by a small group, have greater benefits than larger groups. Olson [26] argues that small groups reach the optimum point of obtaining the collective benefit more easily.

Thus, economic objectives, cohesion and efficiency, control and agility of actions, collective benefit, promotion of individual interest, social incentives, results and the mitigation of free-riders are more satisfactory in small groups. The small group also has fewer opinions, diverges less, is easier to control and organise, and decisions are more agile and easier to make. Therefore, small groups have more advantages over larger groups.

6. Conclusions

Under the lens of the Theory of Logic of Collective Action, this article discussed and analysed aspects of rural collective action Condominiums of Rural Warehouses in the context of Brazilian agribusiness. An approximation of the Condominium Rural Warehouse concept is observed with the Theory of Logic of Collective Action, mainly considering the logic and characteristics of small groups.

Condominiums of Rural Warehouse under the analysis of group formation provide numerous advantages, such as making the warehouse structure collectively viable, strengthening the collective, providing greater efficiency for rural businesses and producers, allowing for the insertion and integration in a competitive market environment, economic benefits, a reduction of costs and increased profit.

The theory explains that besides the non-existence of free-riders, in small groups, the economic objectives, cohesion and efficiency, control and agility of actions, collective benefit, social incentives, results and the promotion of individual interest are more satisfactory.

In addition, based on the Content Analysis, it was possible to establish categories to analyse and discuss the model Condominium of Rural Warehouses under the lens of the Theory of Logic of Collective Action. The warehouse is revealed as the core of the common goal to all farmers. Some benefits are the feasibility of the warehouse structure, dilution costs, realisation with greater strength and the effectiveness of economic goals, obtention of greater profit (direct sales and strategic marketing), reduction of costs and logistical bottlenecks, and aggregation value to the final product. In addition, the Condominium of Rural Warehouses model is formed by a small, restricted and closed group, with a profile of producers ranging from small and medium to the Southern Region, with experience in other models of rural collective actions, as well as relationships of trust and similar ideas.

Regarding the different collective actions in the Brazilian agribusiness, the Cooperatives and Rural Associations that work in storage, agricultural, livestock and rural credit activities stand out. In addition, there are Rural Condominiums, a little-known and lesser-proportioned rural collective action, which operate in different rural industries, such as storage, dairy, pork, coffee and agroenergy. The associative and cooperative culture is predominant in the country's Southern Region, which creates and develops collective actions. Additionally, we see the importance of uniting and forming collaborative groups for local growth, development and agribusiness so that individual objectives under collective action are more easily achieved and more efficient, promoting advantages for the individual, the business and the whole value chain.

Among the main differences between the Warehouse Condominiums and the other rural collective actions, the following stand out for the Condominiums: strategic marketing, direct product sales, higher profit from the sale, owning the storage structure itself, a less bureaucratic model, efficient, greater decision-making power for rural producers, and a reduction of queues for loading and unloading.

Government Economic incentives restrict Condominiums of Rural Warehouses due to the uncompetitive interest rates and high profile for small and medium farmers. In addition, interest rates have increased over the years, discouraging the viability of new warehouses and making storage financing "expensive". It is worth remembering that a storage deficit persists in the country. The lack of warehouses leads to a failure to enjoy the advantages of storage and causes stagnation in the storage sector, silos and similar companies, and for any collective actions involved.

On the other hand, market economic incentives include extra profit provided by direct sales—without intermediaries—and commercialisation at any time of the year. Financial Incentives are essential for the formation and survival of groups in the market, as the activity itself maintains itself and generates profit over the years.

Social Incentives are also achieved in Condominiums, by establishing Warehouses unity among producers through collective action that reflects interpersonal skills, knowledge exchange, technical and professional growth, job creation, and learning. Thus, personal social and psychological characteristics, such as respect and friendship, encourage individuals to organise themselves in groups. In smaller groups, social incentives and 'social pressure' are more easily achieved and efficient, favouring the Warehouse Condominiums.

Furthermore, small groups have more advantages over large groups and are more efficient and effective. Social Incentives work best, and the collective benefit is achieved more efficiently, as claimed by Olson [37]. In addition, small groups have fewer opinions and thus differ less, are more easily controlled and organised, and make decision making more agile and easier.

Furthermore, individual actions in smaller groups are better recognised. Individual efforts will influence the group's final results in small groups more so than in large groups, and there are no free-riders. Thus, in small groups, economic and social objectives, control and agility of actions, promotion of individual interests, cohesion and efficiency, and the results are more satisfactory than in large groups. It is worth mentioning that there may be competition in the market between small and large groups. These are beneficial for the organisation to be efficient, effective and to promote improvements.

Regarding economic determinants, financial gain is a major benefit, the product's commercialization—direct sale and superior profitability—is also a considerable benefit, as is the addition of value, and equity in the form of a warehouse. The logistical constraints provide logistical gains offered by the lack of lines, less flow, and proximity of the storage unit with the rural property. Social conditions are exemplified in the unity of rural producers in creating and developing collective action, exchanging information, personal maturation, and strengthening activity and freedom with the product's sale.

Finally, the model concerns small and medium rural producers, and places with logistical bottlenecks and storage deficits. Rural producers who wish to enjoy the advantages of an association (of collective actions), as well as storage itself, are also targets. There is little knowledge about the Condominium model outside Palotina, Parana, Brazil. The model is generally not known of throughout the country and by Government and Brazilian agribusiness stakeholders.

Rural collective action has recently expanded, mainly in the country's Southern Region, tackling salient issues associated with farming.

In this study, neither quantitative analyses nor statistical programs were used, which act as limitations of this study. Thus, we suggest it for future studies. It is also worth noting that considering that the study has a qualitative approach, it was not intended to produce generalised results. So, we suggest that future studies conduct a comprehensive survey across the country to identify if there are condominiums of rural warehouses in other Brazilian regions and other countries, by using a quantitative approach.

The selection of the study participants can also be recognised as a limitation because it occurred considering the criteria of representativeness, accessibility and convenience, and we interviewed the managers identified using documental analysis, mainly across the Internet and in reports of Brazilian Associations and the report of the pioneer project supported by FAP-DF, Brasilia, Brazil. We suggest that future studies consider other methods to select participants, such as the snowball sampling method in the case of qualitative studies, or quantitative sampling calculations in the case of quantitative studies.

Furthermore, the study has limitations associated with the size of the studied group of rural grain producers. However, there are few collectives of this type in the Southern Region of Brazil. In this way, we managed to analyse production and organisation experiences that represent the recent phenomenon, although limited by the chosen sample. There is a restriction on the extrapolation of results to other Brazilian contexts due to the sample size, the exploratory nature of the research and the particularities of each region in Brazil.

For future studies, we suggest: (i) analysing and discussing the Condominiums of the Rural Warehouses model under the focus of Transaction Costs Theory; (ii) conducting a technical analysis and economic feasibility studies for Silage and Solar Condominiums; (iii) developing a methodology for measuring the cost (value) of the storage quota, considering the possibility of a partner leaving the model, selling the quota or family succession; (iv) measuring the reduction in logistics costs using the Rural Warehouse Condominium model; (v) measuring agricultural marketing margins through Rural Warehouse Condominiums; and (vi) to apply mathematical models to determine the conditions of Brazilian rural collective actions.

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A Multi-Methodological Analysis of Jabuticaba's Supply Chain in an Agricultural Cooperative Production

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Abstract: *Background:* In the late 1990s, the idea of fighting drought gave way to the concept of how to live with drought in the Brazilian semi-arid region. From this perspective, the Brazilian Federal Government's investment in social technology and education encouraged local agricultural production and subsistence agriculture began to have a surplus for commercialization and income generation. However, there are still difficulties in the development of the productive chain, as perceived in Alagoas, Brazil, with the jabuticaba fruit and its derivatives. In this locus, problems related to the creation of value and distributions of the product were identified. *Methods*: This study proposed a participant observation in a rural producers' association and a multimethodological approach based on VFT (Value-Focused Thinking) and SWOT analysis aiming to structure the problem, identify communities' objectives and develop alternatives to solve these problems so that they can get more out of their production. *Results:* showed that the product has marketing potential due to its differential, but the producers are limited in the process of distributing the goods. *Conclusions*: So, this study was able to analyze the problems of this productive system in a structured way, generating suggestions for actions to achieve the strategic objectives of the cooperative.

Keywords: supply chain; structuring problem; family farming; multimethodology

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1. Introduction

Balancing environmental sustainability with economic and social growth is a challenge for current and future generations. The high consumption rates of the world population, along with population growth, have driven the production of various industrialized products in recent decades. However, at the same level, a chain based on conscious food consumption has grown through a sustainable production system [1].

For [2], agriculture and the food systems it supports are at a crossroads. Despite recent technological advances in food production, almost one-third of food produced for human consumption, equivalent to a total of 1.3 billion tons, is lost during the production process up to the food processing stage or wasted at the food service and consumer level [3].

Given this scenario, there is a need to discuss sustainability and supply chain management practices [4]. Sustainable supply chain management (SSCM) refers to the management of resources within a company and the collaboration of members along the supply chain, taking into account the three dimensions of sustainable development that are required from customers and other stakeholders [5].

Brazil is one of the world's leading food producers and an important supplier of commodities to the global market [6]. However, the sector has high levels of food waste, with Brazil being among the top ten food-wasting countries in the world [7]. This demonstrates the importance of the theme and the need to analyze this chain.

The semi-arid region of Brazil is the one with the highest rainfall index in relation to other semi-arid spaces in the world [8]. However, it is one of the least developed in terms of appropriate technologies, and became so during the 2000s due to actions by the Brazilian federal government and the Articulation of the Brazilian Semi-arid (ASA), guided by the perspective of living with the semi-arid [9].

Institutionally, from the 1900s to the 1990s, the State was the actor with the greatest prominence in actions, specifically those to combat drought and those focused on technical aspects for cultivation and animal husbandry [10]. Between the 1990s and 2000s the Community, another institutional actor, composed of family farmers, cooperatives and associations, begins to legitimize its actions aimed at coexistence with the national semiarid [11].

To support family farming, the Community started to have food for subsistence and also to sell to State programs (National School Feeding Program (PNAE) and the Food Acquisition Program (PAA). Linked to the perspective of autonomy of the family farmer [12], to fix him even more in the Brazilian semiarid region, the insertion of the logic of the market has encouraged the opening of urban fairs composed of products from family agriculture, in which many have even started to seek, according to [13], organic certification.

Considering such aspects, there is an example of a cooperative in the semi-arid region of Alagoas, Brazil, that produces several agricultural products, but has stood out with the production of jabuticaba fruit. With this opportunity to commercialize their products, but with the inefficient logistics aspect, this study proposed a combination of SWOT analysis and Value-Focused Thinking (VFT) with the objective of structuring the problem, identifying the communities' objectives and developing alternatives to solve these problems so that they can get more from their production.

As contributions of this work, we can highlight: (a) better understanding of the problem situation through the steps of SWOT analysis and Value-Focused Thinking (VFT); (b) understanding of the operational techniques and the chain of small rural producers; (c) support for decision-making in the development of alternatives to solve these production problems.

Section 2 shows a brief literature review addressing food supply chain issues and recent publications related to the methodology applied in this study. A description of study locus and problem situation is presented in Section 3. The construction of the methodology applied with the cooperative is presented in Section 4, whose results are detailed in Section 5 along with the discussion and implications of the study. The last topic has a conclusion about the studies and ideas for future work.

2. Literature Review

This topic presents the theoretical elements that will guide the proposed discussions. Thus, we present the concepts of the Food Supply Chain and some application cases.

2.1. Food Supply Chain

Within the agri-food scenario the creation, functioning and evolution of food-supply chains, as well as studies on the unfolding of this reality, have become a key dimension in the development of new patterns of the rural production process [14,15]. In this regard [16] define that the food supply chain can be divided into five stages, including agricultural production, post-harvest handling, processing, distribution (retail or service) and consumption.

The phenomenon starts to be observed under the scope of food chains defined as alternatives, which are networks presented from a new policy and from aspects arising from an interest and demand for foods considered "more natural" and healthy [14,17]. This policy is responsible for distancing itself from the production of food with an industrial focus, essentially globalized, a mechanism that finds some limitation when consumer concerns with safe food are identified, together with perceptions from cultural dissonances that interfere in food tradition, limiting the action of globalization and leading to a reflection of changes in the commercialization of agricultural products [17], being centered since the beginning in the conjugation of initiatives appropriate for this approach such as "organic agriculture, fair trade, local products, and short food supply chains" [18].

This approach tends to cause discontinuity in the long industrial chains, which are naturally permeated by a common complexity and organization typical of this conglomerate with global reach, leading to production based on associative networks that differ from the traditional supply chain [19–21] relate that the ability to re-socialize and re-spatialize are peculiar to short food supply chains, as they allow consumers to make value judgments about the relative desirability of food based on their own knowledge, experience, or perceived image, thus dynamizing the existing relationship between producer and consumer.

Producer–consumer relations are important in this scenario because it is from this significant interaction that increasingly complex and diversified interfaces between these players are designed, in terms of the types of relations and organizational characteristics that they exhibit [21].

According to [15], the instances acting in this sector face complex issues, occasioned by additional marketing uncertainties and a shorter product shelf life, demanding the formulation of specific planning models that incorporate issues such as harvest policies, marketing channels, logistic activities and even risk management. Short supply chains can be identified as expressions of attempts by both producers and consumers to match new types of supply and demand [21].

2.2. Background

With the attention focused on the supply chain of agricultural products in recent years [15], when analyzing the essays that address the food supply chain theme, it can be noticed that its authors use several contexts to develop their approach about the subject in question.

Applied through the concept of circular economy, a food supply chain analysis is viewed from the perspective of the barriers encountered to establish the practice of this economic approach in food supply chains in the studies of [22]. In this manuscript, barriers are identified in the context of food-supply chain as the following: "cultural", "business and corporate finance", "regulatory and governmental", "technological", "managerial" and "supply chain management", with the development of practices allusive to Industry 4.0 being proposed as a way to overcome such challenges encountered.

Anchoring in discussions around circular supply chains, [1] in turn infers that the practice can exponentially generate value-added food, identifying that in this there are also considerable risks, suggesting the Internet of Things and an efficient management system within a supply chain as ways to ensure high transparency, interconnectivity and therefore efficiency in the process.

Still under this perspective of analysis of agri-food systems through the supply process, [23] performs, from a comparison of olive oil food supply chains, the inference that there is a greater appreciation among the compared agricultural products, from short supply chains, confirming trends and perspectives already observed in the literary context of the study in evidence.

Following this line [24], through Community-Supported Agriculture (CSA), which consists of shortening the food-supply chain, based on the understanding of this as a practice that goes beyond the maximization of profit derived from the family model, identifies through analysis of the applicability of this methodology in aquaculture management in the Barycz Valley, located in Poland, that the practice can become a necessary support for the sale of the product despite the local conditions not being favorable, in their entirety, to its development.

When conducting a study on the logistics of a short food-supply chain, ref. [25] point out the importance of logistics in the performance of short food-supply chains, as this is a challenge and is seldom discussed among researchers in the field, besides inferring that a series of actions should be considered in the itinerary of the implementation of this supply modality, such as the need to make sustainable environmental choices during all stages of food distribution, optimization of the location of the nodes in the supply chain, improvements in the distribution route and restructuring of the supply chain, as well as contributions by farmers, ranging from the adoption of open approaches to the application of innovative distribution systems to vertical and horizontal collaboration and even cooperation with researchers.

Focusing on the understanding of the developments caused by food chains in forest regions, [26] reference the discussion if the policies found in the supply chain implementation interfere in the livelihood results. They identify that certification and code of conduct policies applied to the research units of analysis interfere with positive outcomes through increased farm income for some businesses, although when simultaneously comparing cases of conservation and livelihoods, they did not identify evidence of trade-offs between these factors.

In part of the recent articles it is common to find discussions and propositions by scholars about the innovation that can be implemented within the supply process of a food chain, whether in its technical or practical aspects. In this way [27], p. 14, understand that the innovations brought by means of digital technologies were able to provide an improvement in the links between the stakeholders of the agri-food chain, since "consumption, production and distribution are the segments of the agri-food chain where most of these digital technologies operate".

The works by [28,29] carried out a survey of the key factors in the production chain of Brazilian family farming: discontinuity in product supply and production scale; demand; production outlets and commercialization channels; credit structure; government support and technical assistance; technologies; market information and market competition, among others. Some of these factors will be analyzed in the object of study in question.

Refs. [30,31] use a SWOT analysis to identify the aspects that influence small producers in sustainable development practices regarding their production. Meanwhile, Patidar, Agrawal and Pratap (2018) identify the development strategies aiming at the sustainability of the Indian supply chain as weakness and strengths through SWOT analysis.

The VFT method has been used in several contexts, including those related to rural and environmental issues; refs. [32,33] use VFT for structuring problems and discoveries of difficulties in the reverse logistics process of manufacturing coffee capsules.

The literature has shown the importance of using sustainable tools incorporated in the production process in the food-supply chain, using different approaches and analyzing different contexts in an attempt to measure these impacts. There is also emphasis on the need for analysis in shorter and more rudimentary chains, as is the case of the object of this study.

The literature review allowed for a better understanding of the problem and indicated the similarities of techniques and results found. This demonstrates that there are no works that classify the "values" of the VFT from the SWOT analysis in similar contexts. Although they are not new methods, it is a different approach which reflects the paper in a practical context.

3. Problem Situation

The cooperative object of study called Cooperativa Mista de Produção e Comercialização Camponesa do Estado de Alagoas (COOPCAM), which opened in 2011, is located in the following border communities: Serra das Pias, Serra Bonita and Monte Alegre. All are part of the rural area of the municipality of Palmeira dos Índios and are composed of 15 families that operate in three main fronts regarding the commercialization of products: vegetables; plants—especially the succulents—and the jabuticaba processed products, from the liquor (produced since 1970), the fermented (produced since 2018) and the sweet (produced since 2020). For these three fronts, from cultivation, harvest, elaboration to commercialization, the actions are carried out by the community itself.

Regarding the geographical space, there are about 815 (eight hundred and fifteen) jabuticaba trees irregularly scattered. The curious thing is that none of these were planted by local people, whose local records indicate that there has been human presence for more than 100 (one hundred) years. The whole scenario of this flora was formed naturally, mainly due to the movement of the birds and local animals that consume the fruits and leave the seeds in the area, considered to be an agroforest, since jabuticabeira, jackfruit, orange, cashew, umbuzeiro and coffee trees coexist in the same space.

The relationship of these residents with the processing of jabuticaba fruit dates back to the mid-1970s, when an employee of the state agency, the National Institute for Colonization and Agrarian Reform (INCRA), provided a recipe to a resident who started producing what is locally called jabuticaba wine. Figure 1 is a flowchart that summarizes the stages of the supply chain of its production.

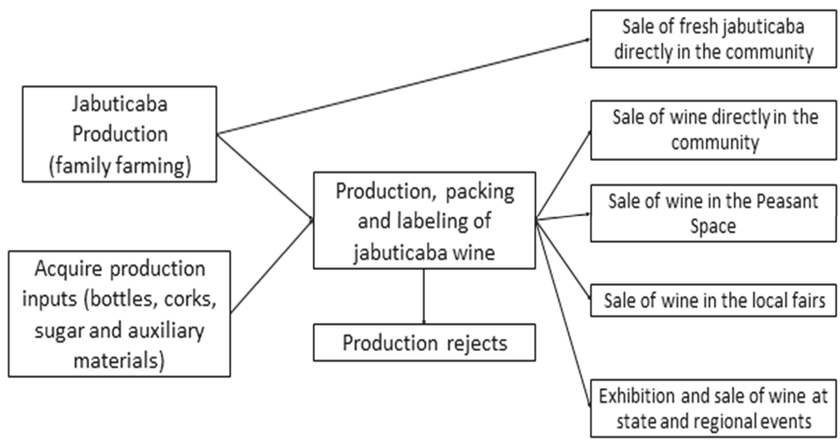

Figure 1. Jabuticaba supply chain in Palmeira dos Índios.

This community production process involves the participation of local residents from the harvest. From preparation to tasting, it has historically been much more symbolic, immaterial and cultural. However, since 2015, the residents have approached the market logic, starting to market—in local fairs and in state and regional events, both linked to the semiarid theme—the hitherto named jabuticaba wine.

Looking at the supply chain considering the post-production stages, it is verified with respect to the sale that there is: (i) the so-called Peasant Space, built in 2016 on the side of the road, for the disposal of their production. In this space, the logic is for the consumer to travel to this specific place to buy the products. Still under this logic, the products are also marketed when (ii) interested parties seek out the residents in the community itself to purchase the products. In order to bring the products closer to the consumers, (iii) the residents themselves take the products for sale in local fairs. However, in situations where displacement is necessary on the part of producers, they face the difficulty of not having a vehicle to transport this production and, therefore, are always below the local potential.

When the focus is on the stages preceding the production of wine, besides the production and harvest of jabuticaba, there is a local campaign for the donation of wine bottles, which are sanitized in buckets and then bottled using cork stoppers bought by the farmers. In this sense, the limitations are about the dependence on donations of bottles and the purchase of cork stoppers which, currently, counts on only one supplier.

4. Methodology

This research can be classified as descriptive and qualitative because it describes the characteristics of the phenomenon and uses a qualitative approach to analyze the problem and to propose an objective framework and alternatives. This study also contributes to the literature in the field of management, because it considers and respects the locus as a realm of singularities. Its participants understand and act on a given context, from which historically was constructed as satisfactory, considering its own contingencies and complexities [34]. Based on this assumption, the tools and theory in management (the inputs) are not imposed, but they are inserted on their own merit, that is, based on empirical demands.

Values-Focused Thinking [35] and SWOT analysis form the methodological basis of this study. Data collection is based on participant observation and interview (Appendix A). In the participant observation phase, one of the authors participated in immersion with the entire production process, from the harvesting of the Jabuticaba fruit to the sale of the products. The producers are asked generative questions, that is, when a question is asked to the participant in order to instigate him to narrate, with a historical–temporal trajectory, the situations that correspond to local characteristics of the order participants [36]. Thus, the generative question for each participant was: We tell, freely, your trajectory—from the beginning to the present day—to organize the production and marketing of jabuticaba—derived products.

The participant observation is the result of an extension project of the Federal University of Alagoas with rural producers since 2018. In order to understand the phenomenon of production and the difficulties faced by producers, some studies have been conducted since then through direct observation. The interviews developed for the present manuscript were conducted in 2021. Figure 2 summarizes the steps to achieve the research objectives.

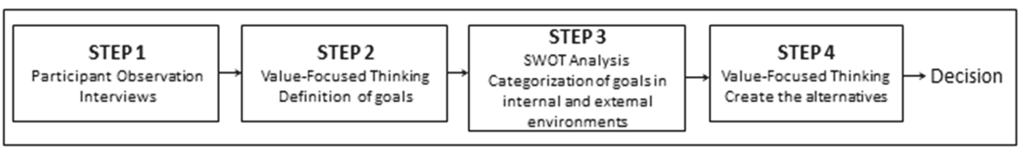

Figure 2. Research flowchart.

Afterwards, interviews were conducted in two stages with four participants—community leaders in relation to local management, harvesting, production and marketing—when investigations were made according to VFT and SWOT. Thus, part of the framework was designed from participant observation and part from interviews. The interviews aimed at a more comprehensive understanding of the situation considering the farmer's own view and also aimed at validating the results.

The author of VFT points out that common thinking about situations, where the decision-maker first thinks about the problem and then thinks about what he wants to achieve, reasoning is limited to obvious solutions and new opportunities go unnoticed. He classified these methods as Alternative Focus Thinking. In contrast to these methods, when a decision-maker structures the situation by prioritizing the understanding of his own goals and how to achieve them, it is called values-focused thinking. The method developed by Keeney is its namesake [35].

Thus, VFT is developed in order to define and organize the objectives of the people involved in this decision environment. Thus, it can be divided into three steps: identifying objectives; connecting related objectives and classifying them; developing alternatives that best fit these objectives. The third step is the key point of VFT since it directs actions towards the realization of its objectives, rather than just solving a problem.

The identification of goals was achieved by asking "what do you want to achieve?", "where do you want to go?", "is there something wrong?", "what is preventing you from achieving them?", and so on. These are the main interview questions.

The second step, by connecting the related objectives, allows you to build a representative framework and classify the objectives into means objectives (necessary to achieve another objective), both fundamental (issues central to the situation) and strategic (aspects central to the organization's strategy). By looking at the structure of the objectives, alternatives/actions can be developed in order to achieve them one at a time or sometimes a single alternative can also benefit several objectives at the same time.

However, some aspects relevant to achieving these objectives may not necessarily be under the control of the decision-maker. For this reason, a SWOT analysis was implemented on the exploration phase of the VFT objectives by classifying key means and objectives as related to a Strength, a Weakness, an Opportunity or a Threat [37–39]. In this way, the course of action to be designed to achieve the objectives takes on different characteristics:

- For those categorized as Strength, actions are directed to take more advantage of these aspects—it depends only on themselves;
- For Weaknesses, actions are directed towards eliminating these negative factors—this also depends only on themselves;
- For Identified Opportunities, actions are aimed at preparing the organization to get the best out of itself—but occurrence depends on external factors;
- For Identified Threats, actions focus on how to deal with these situations that are not under the organization's control and can negatively influence the business.

Following the above description, the next section describes the results obtained and presents a discussion about them.

5. Results and Discussion

This topic presents the elements obtained through participant observation, the application of the VFT method, and the SWOT analysis to understand the problem and propose alternatives.

5.1. Results from Participant Observation

The participant observation data demonstrated the compositions of the Jabuticaba fermented productions in 2019 and 2020. It was verified that the 2020 production had a sharp increase compared to 2019, taking into account the good harvest obtained in the respective fiscal year. Therefore, the production had a positive variation of 152.86% (1770 L) in 2020, as opposed to the 2019 production (700 L).

In addition, the behaviors of the finished product losses were observed. It was seen that the finished product loss had a positive variation, that is, an increase of 12.39% (525 L) between 2019 and 2020, an elevation caused by the following relationship found: proportionally, the more one produces, the greater the loss of the product produced.

Thus, it is notable that the lack of mechanization and the adoption of rustic methods to the production process of COOPCAM in the production of Jabuticaba wine causes this loss of product to be intensified. Moreover, the cooperative no longer commercializes this quantity of wine, which results in an increase in the cost of the liter produced, considering this loss as "normal" within the production process.

Regarding the finished product for sale, it was observed that despite the increase in production between 2019 and 2020, the quantity of product sold suffered a decrease. This occurred mainly due to the fact that the jabuticaba fermented fruit has a dry-type flavoring, since sugar and cachaça, both used in the production of jabuticaba liqueur, were removed from the production process. Choosing to produce a fermented wine caused the sales positioning to be redirected to a more urban public that also appreciated dry wine.

Besides structural issues, the difficulty encountered by local farmers is in relation to the distribution of their products derived from jabuticaba, because they need the following:

- Appropriate logistical support, from the harvest to the transport to the production headquarters;
- Logistical support to commercialization places in other potential municipalities such as the capital, Maceió and other states;
- Storage of the jabuticaba, because it is a fruit that ripens and degrades very fast due to its rich composition of sugars and nutrients. The refrigeration structure is insufficient;
- It is still necessary to determine the chemical composition of the product to define the alcohol content of the drink. This is an important factor for marketing the product in other states, including with regards to air transport of the product for commercial flights by passengers, if they purchase the product and want to take it as souvenirs.

The survey of key factors in the production chain in Brazilian family farming during the participant research was performed by classifying them according to elements pointed out by literature. The authors mention recurrent problems in family farming, some of which were also identified in the present case, as described below.

- Discontinuity in product supply and production scale.

The jabuticaba liqueur had been produced since 1971 (although it was always called jabuticaba wine) for their own consumption in the June parties in the rural area of Palmeira dos Índios. The production of the wine itself started in 2019 and occurs only in the months of March to June and depends on the rains in the region. It is planned for 2021 to create new products derived from the jabuticaba fruit, such as the sweet of the fruit and the sweet of its peel, in addition to the fermented fruit and the liqueur.

- Demand, production outlets and commercialization channels.

Limited demand for the product due to difficulties in transportation to the commercialization sites. Product has demand; however, the cooperative does not yet have good logistic capacity for its distribution. The labels do not yet meet the required standards, which makes it difficult to deliver the product and sell it in larger centers. Sales are mainly due to the participation in agroecological fairs and from clients who already know the product. For now, sales take place in the current physical space, at fairs and/or by order.

- Credit Structure.

The resources for the actions and investments come from the MPA (Small Farmers Movement) and from COOPCAM (Cooperativa Mista de Produção e Comercialização Camponesa de Alagoas), in addition to the resources from the sales of vegetables, liqueurs and fermented products that are being used to build the production space and to acquire new production equipment.

- Government support and technical assistance.

Government support is provided through technical assistance from the following agencies: EMBRAPA Alagoas, Sebrae, the Alagoas Maior Program [Alagoas government], the ECOFORTE project with AAGRA (Alternative Farmers Association) and research from UFAL (Federal University of Alagoas).

- Technologies.

The production process is going through a modernization process. Stainless steel barrels were purchased for the fermentation of the beverage, and a cistern was built to catch water, which is scarce in the production space. The organization of the production system was started, identifying processes and organizing flowcharts.

Several aspects were related in the participant observation. In order to organize the problem situation, the next section describes the results of the VFT as a tool for structuring problems and defining strategic decision elements.

5.2. VFT-SWOT Situation Structuring

Once the description of the environment was made, one could see that several problems are faced simultaneously. In order to organize the constituent elements of this problem and transform them into objectives, the information was organized according to the Value-Focused Thinking methodology. Thus, with participant observation it was possible to identify elements related to what is wrong and the constraints of the activity, which were already converted into objectives to adjust or eliminate them. In other words, it comprises part of the first VFT stage of identifying objectives.

This step was then complemented with questions to identify the objectives, as described in the methodology, as well as with questions directed at the identification of strengths, weaknesses, opportunities and threats. In this way, we identify the objectives that represent the internal and external factors to the organization, that is, what is and what is not under the control of the community itself, respectively.

Therefore, the SWOT analysis has the role of balancing the result of VFT on the creation of alternatives and decision opportunities, since the method of acting by the organization is different in face of the objective that is being considered, as stated in the methodology. Therefore, the SWOT analysis is a robust and extremely effective technique; it is found to be very helpful to clearly point out the current flaws and provide future direction [39]. Figure 3 presents the identified objectives already with their relations and classified as medium, fundamental or strategic and as to the SWOT quadrants. Thus, Figure 3 is a result of the problem structuring, which facilitates the understanding of this complex environment through a graphical representation. Furthermore, it serves as a guide for the proposition of solutions.

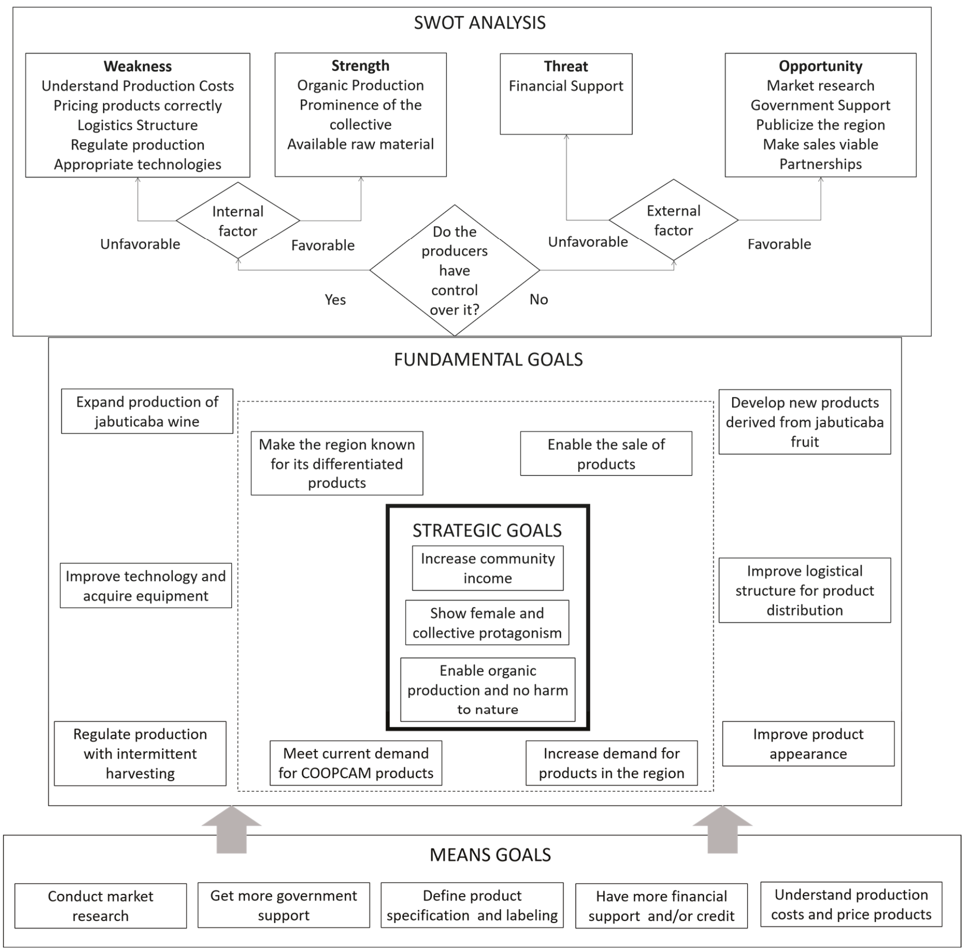

Figure 3. Flowchart of VFT objectives and SWOT analysis.

The means objectives are those necessary for the achievement of the fundamental objectives. Market research is necessary to understand consumer behavior regarding the acceptance of current products and the new products to be developed, as well as to measure the size of this market, essential for planning production capacity. The dimensioning of production, as well as the feasibility of trading the community's products, depends on the understanding of costs and the consequent definition of prices in a way that at least covers the production costs and expenses, besides providing a profit margin.

Note that some production and product problems may be related to the lack of specific technology and equipment, as well as to the increase in production capacity to serve current and new markets. There is also the serious problem of the lack of vehicles, which makes it impossible to sell even though we have the production capacity and expectation of demand. For such investments, it is necessary to have more financial resources available.

Labeling products, including their specifications, is necessary to explore new markets. For some occasions, such as air transport, it is mandatory. Furthermore, they can take advantage of this need to create a label and turn it into an opportunity to improve the appearance of the products, which increases the demand for products of the region, making it also better known.

The support from the government and other institutions influences the dissemination of the community, can support fundraising, but also promotes interinstitutional cooperation, making it have more technical and technological support for the development of its activities, and adjust production and agricultural technology.

At the center of the objectives are the strategic ones. They are considered so because, according to the answers given, they are central issues and are not being considered so that it is possible to achieve other objectives. It is understood as the purpose of the business, therefore, to make the production and commercialization of organic products viable, to highlight the community as well as women's work, and to bring a better financial condition to the community. With good financial planning it is also possible to reinvest in production. However, this is a later stage that depends beforehand on the achievement of the means and fundamental objectives.

With the objectives defined, these were segmented into the quadrants of the SWOT analysis. According to [40], the elements that compose the SWOT analysis must be understood according to the following elements: "S + W" factors include: (1) management ability; (2) technological ability; (3) financial ability; (4) organization; (5) operations "O + T" factors include: (1) social and political context; (2) economic context; (3) market opportunities; (4) competition mechanisms.

The objectives were then grouped into internal and external factors, and again grouped into strengths, weaknesses, threats and opportunities. With this defined, the process becomes clearer for the establishment of alternatives. It is worth noting that according to [35], the first alternatives created are generally the most obvious, those that have been used before in similar situations and those that are already widely available. The development of alternatives is initially based on the means objectives themselves and by combining them in order to develop alternatives that satisfy more than one objective simultaneously.

The alternatives can be seen in Table 1, and are classified according to the control capacity (external or internal factor to the community) and related to one or more objectives. These alternatives, since they are created based on intermediate objectives, are considered for a quick start (short term), since not reaching these objectives can delay the achievement of the organization's strategic objectives.

A1 is a course of action that is considered external because it depends on the approval of another institution to be confirmed. The region has public university centers, as well as public institutions that promote projects aimed at improving productive systems. A2, in turn, depends exclusively on the cooperative itself. Understanding the production costs of the products is fundamental for a correct definition of the operational result and calculation of the profit of the cooperative. Costs are also used to make decisions about production mix and investments. If managers do not have knowledge about costing tools, the partnerships reported in A1 are also suggested for this activity.

Although currently, due to various restrictions, it is not possible to meet all the perceived demand, the market study is necessary (A3) since making investments without a better commercialization perspective can be risky for the cooperative. Therefore, it is interesting that this is one of the first actions to be taken. Furthermore, market research can be used to attract investors or justify public funding needed to expand and improve production and logistics activities (A4).

Table 1. Alternatives identified.

ID	Alternatives	Internal or External?	Related Objectives
A1	Seek partnerships with public institutions to provide support in determining product characteristics for specification and insertion of information on labels.	External	Define product specification and labeling Get more government support
A2	Analyze the composition of the production costs of each product individually to support the pricing and financial management of the organization.	Internal	Understand production cost and pricing products
A3	Conduct market research to understand the real demand for the products	Internal	Conduct market research
A4	Seek government support to obtain funding for the investments needed by the organization	External	Get more government support Get more financial support/credit
A5	Assess the current state of finances for reinvestment of financial resources in one's own activity	Internal	Get more financial support/credit
A6	Seek interinstitutional and governmental partnerships for support in • Agriculture techniques; • Production and quality-management techniques; • Logistics; • Marketing.	External	Get more government support

A similar reasoning of A2 can be applied to A5. Besides establishing a cost structure, it is necessary to study the financial and budgetary capacity of the organization in order to evaluate the reinvestment capacity. This alternative gains even more importance in a possible denial of the external investment alternatives. It is worth pointing out that in this issue one faces a dilemma, since the income of the communities that are part of the cooperative is also a strategic objective. Then, this reinvestment must be discussed internally so that this investment possibility does not harm the community's income at this time.

A6 refers to the interinstitutional support in the various stages of the jabuticaba production chain. The difference between A6 and A1 lies in A6's long-term vision. While A1 refers to the adjustment of an already commercialized product, with punctual improvements. A6 refers to studies and actions that will bring returns later. As examples, green production techniques, both agricultural and manufacturing, can be applied to increase productivity, marketing to increase brand value, logistic organization and other actions in partnership with specialists.

These alternatives are not prioritized. It is understood that they are urgent actions for the organization. The prioritization may be the result of another study, but concerning the activities that will be carried out to achieve the fundamental objectives. It is worth mentioning that this work was limited only to the proposition of alternatives, which will be presented to the rural producers; however, their application and analysis is beyond the scope proposed here.

6. Conclusions

Family farming has improved the quality of life of several small producers throughout the Brazilian territory, by offering an income expectation through the commercialization of their products. However, a series of barriers have been presented by these producers throughout their production chain, as is the case portrayed in this article.

The methodology proposed in this article sought to identify the main problems presented in the production chain of the jabuticaba fruit, through participant observation. With this, it was possible to understand that despite the great potential presented by the product for commercialization, the producers presented problems in the production, sale and delivery of the goods.

The use of the VFT approach combined with the SWOT analysis made it possible to identify the main objectives (means, fundamental and strategic), categorize them in the internal and external environments and, at last, propose some alternatives that could subsidize the decision process from short- to long-term. With this, producers can clearly identify the actions to be taken for operational, managerial and strategic improvements. The methodologies are especially useful and easy to reapply to similar contexts and situations.

The alternatives or actions recommended in this study aim, therefore, at concentrating efforts to meet the objectives indicated by the cooperative members themselves. The recommendations of this study aim, therefore, at concentrating efforts to meet the objectives indicated by the cooperative members themselves, but also deepening this vision from the participant research. This step, along with the VFT and SWOT, made it possible to see problems and alternatives whose relationships and importance were not necessarily clear. With this, producers can clearly identify the actions to be taken for operational, managerial and strategic improvements. The methodologies are especially useful and easy to reapply to similar contexts and situations.

The main limitation of the work is due to the characteristic of decision support methods, since a result is valid only for this particular situation, at this moment and with this group of decision-makers who answered the questions. Changes in these aspects of the decision environment may lead to different results. For future work, the use of the multi-criteria decision support approach is suggested for bidding the weights and criteria of the producers, as well as in the ordering and prioritization of alternatives, especially when the means objectives are being met.

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Appendix A

Questionnaire

Objective: The questions were designed to identify the operation of the production chain of items produced with jabuticaba fruit.

These must be answered in the following aspects (Q1 and Q2):

(a) Management resources;
(b) Technological inputs;
(c) Organization;

(d) Operation.

Q1: What are the strengths of the production of items related to jabuticaba?

1.1 What are the advantages of producing using jabuticaba?
1.2 What factors make the product competitive and accepted in the market?

Q2: What are the weaknesses of the production of items related to jabuticaba?

1.3 What could be improved in the operation of the business?
1.4 What is not done correctly in production?
1.5 What obstacles prevent the regular marketing of products?
1.6 Which aspects of the Jabuticaba chain can be strengthened?

These must be answered in the following aspects (**Q3 and Q4**):

(a) Social and political context;
(b) Economic context;
(c) Market opportunities;
(d) Competition/Competitors Mechanism.

Q3: What are the opportunities Farmers can explore to produce jabuticaba fruit and its by-products?

1.7 What are the possibilities that producers identify in the production of items related to jabuticaba?
1.8 What benefits would producers have with the production of items related to jabuticaba?

Q4: What are the threats that Farmers might face when in production of jabuticaba fruit and its by-products?

1.9 What external obstacles do Producers see in the production?

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The Role of Logistics in Food Waste Reduction in Wholesalers and Small Retailers of Fruits and Vegetables: A Multiple Case Study

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Abstract: *Background:* There is a lack of studies on the waste of fruits and vegetables covering both distributors and the retail sector. Our study advances from previous ones by proposing the analysis of local retailers of different sizes and wholesalers. Our objective was to analyze the logistical practices to reduce the waste of fruits and vegetables in wholesalers and small retailers in Federal District, Brazil. *Methods:* A multiple case study was conducted with 19 retailers and eight wholesalers. We administered semi-structured interviews and performed documental analysis and direct observation. *Results:* The findings demonstrated the leading logistical practices of handling, conservation, management and control, and consumer awareness about food waste. The type of retailer was limited to grocery stores and fruit shops, and the type of food covered only fruits and vegetables. Furthermore, we considered the food waste generated in the logistics processes and not that after consumption. *Conclusions:* More than a third of the food produced worldwide is lost or wasted. A considerable part of the food waste is associated with the lack of an adequate structure of the logistical processes. The results may contribute to the adoption of practices related to reducing food waste by retailers and wholesalers.

Keywords: food waste; logistics; retail; wholesale; supply chain management

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1. Introduction

Despite the expeditiousness of world food production, the United Nations Food and Agriculture Organization [1] points out the need for a 60% increase in global food production by 2050 to meet the population's growing demands. Brazilian agricultural production has grown markedly in the last decade, facilitating the reduction of poverty and hunger in the country [2]. Specifically, in relation to fruit production, Brazil stands out as the third largest world producer, responsible for approximately 45 million tons of produce every year, with about 65% for domestic supply and the remaining 35% destined for exportation [3]. Additionally, the Brazilian vegetable chain presents various options, concentrating its production volume on the following species: potato, tomato, watermelon, lettuce, onion, and carrot [3].

Although the volume of food production in Brazil is enormous, a substantial part is wasted [4]. Brazil wastes around 41 thousand tons of food per year [5]. Worldwide, more than a third of the produced food is lost or wasted, equivalent to about 1.3 billion tons of food [6]. Among the amounts lost or wasted, 30% corresponds to cereals; between 40% and 50% comprises roots, fruits, vegetables, and oilseeds; 20% involves meat and dairy products; and 35% is fish. It is estimated that these foods would be enough to feed two million people [6]. Within this context, reducing food losses and waste should be a priority for establishing productive structures and structures of sustainable consumption [1]. The irrational use of food harms humanity [7]. Understanding food waste is crucial as it affects food chains. For example, the European Union and other high-income countries have significantly higher levels of food waste [8]. In developing countries, such as Brazil, waste is mainly linked to the initial stages of the supply chain involving harvesting, transportation, storage, and distribution [9]. About 30% of the total vegetables that pass through the distribution centers are lost, with only 70% being marketed [10].

Analyzing the overview of worldwide studies, it is possible to verify an emphasis on the valuation of the final consumer behavior [11–13], the measurement of the wasted quantities [14,15], and the environmental and monetary impacts generated by food waste [16,17]. In Brazil, some studies have addressed food waste under the perspective of logistical bottlenecks [18]. The authors approached specifically the handling and transportation activities, verifying the rates of losses of vegetables and fruits. Other studies addressed the role of packaging and the supply chain's coordination structures to reduce food waste [19]. The use of food waste in a different production process was studied by Belik et al. [20] and Fagundes et al. [21]. Finally, some studies stressed the causes of food loss and ways to reduce food waste [22–24].

Considering this scenario, there is a lack of studies on the waste of fruits and vegetables covering both distributors and the retail sector. Thus, the present study advances from previous ones by proposing the analysis of local retailers of different sizes and wholesalers. This paper aims to analyze the best logistical practices in reducing the waste of vegetables and fruits in retailers and wholesalers located in the Federal District, Brazil. For this purpose, this study was composed of two parts: first we identified the causes of waste through a systematic literature review, considering Brazilian and international studies, and second, we carried out an analysis of multiple cases through direct qualitative interviews conducted with 19 managers/owners of fruits and vegetable stores and eight wholesalers, who supply the fruits and vegetables to the stores. The data analysis was carried out by means of categorical content analysis.

The main contribution of this paper is twofold: (i) the systematization of the best logistical practices of fruits and vegetables to avoid food waste employing a systematic literature review; (ii) the analysis of the best logistical practices to reduce the waste of fruits and vegetables adopted by retailers and wholesalers in the agri-food chain, in terms of handling, conservation, management and control, and awareness.

2. Literature Review

2.1. Agri-Food Supply Chain and Food Waste

The agri-food supply chain refers to a series of relationships in different segments that establish successive exchanges in transforming inputs into value for the final consumer [25].

The agri-food supply chain starts at the point "Before the Farms", covering the activities related to inbound logistics and companies that supply raw materials to be used in the production process in the field, such as seeds and agrochemicals. Then, there is the link "On the Farms", which considers the improvements that products still receive inside the farms: weighing, pre-washing, selection, cooling, agro industrialization, and packaging. The last link, which is the focus of this research, is the "After the Farms" phase, covering outbound logistics activities, including activities of handling, storage, warehousing, and transport. It considers attempts to sell products to industries and other distribution channels until they reach the final consumer [10].

Within the agri-food supply chain, specifically for fruits and vegetables, food waste can occur, mainly due to the high perishability of the product and incorrect handling and transportation. It is essential to point out that there are two main types of food waste. When there are losses until the process of distribution, we call them "food losses". After the distribution process in several channels (wholesalers, retailers, small stores, fairs, direct sales to consumers) and after the sales, at the consumers' residence, we call them "food waste". This study is focused on the food waste occurring in retailers and wholesalers. In this process, many products that individuals can still consume are discarded. The waste of fruits and vegetables is mainly associated with the behavior of wholesalers, retailers, other food sales services, and consumers [6]. Food waste encompasses all food discarded in the marketing stages by retailers and wholesalers, in which the food is discarded under full consumption conditions since it would still meet nutritional needs [9].

It is noteworthy that a considerable part of the waste is associated with the lack of adequate structure of the logistical processes involved [4], which is the focus of this study. The way the supply chain components are structured directly influences the quality of the products [25]. Furthermore, errors in demand forecast, inefficient replenishment policies, and high product quality demand can contribute to food waste [26]. Structural problems, such as planning and logistical bottlenecks, limit improvements in Brazil's fruit and vegetable supply chain stages [27]. After the harvest, food waste in Brazil is caused by improper packaging, lack of product refrigeration, improper handling, poor display of products on the shelves, deficiencies in transportation, and incorrect handling by consumers [28].

In this sense, reducing food waste is a challenge that requires enhancing the efficiency of the operations and logistics [29]. It may include infrastructure and hygiene care advances and better management and conservation of the fruits and vegetables in the market [30]. Furthermore, improvement in logistics, cold chain management, retail packaging, and consumer awareness publicity can prevent food waste [31].

2.2. The Best Logistical Practices to Reduce Waste of Fruits and Vegetables: Systematic Literature Review on Brazilian and International Publications

In order to get the leading logistical practices aimed at reducing the waste of fruits and vegetables, we conducted two systematic literature reviews. This section presents the results of the literature reviews, on the basis of which category construction was carried out for data collection and analysis. The description of the used protocol to select and filter papers is included in Section 3, related to methodological procedures. Table 1 shows Brazilian and international publications' analysis of best practices in logistics to reduce/avoid food waste.

Table 1. Best practices in the logistics stages to reduce and/or avoid food waste.

Best Practices	Stage	Authors
Environment climatization (temperature, humidity)	Planting, transportation, storage, warehousing, commercialization	Almeida et al. [24]; Ceccato and Basso [32]; Tofanelli et al. [23]
Improvement in product quality (standardization and classification)	Planting, acquisition, commercialization	Ceccato and Basso [32]; Tofanelli et al. [23]; Tofanelli et al. [33]; Lourenço and Katz [18]; Ribeiro et al. [34]; and Brandão and Arbage [19]
Proper handling care when handling food	All stages	Ribeiro et al. [34]; Almeida et al. [24]; Tofanelli et al. [23]; Fagundes et al. [21]; Belik et al. [20]; Lourenço and Katz [18]; Buzby and Hyman [35]
Proper packaging	Transport, storage, warehousing, commercialization	Almeida et al. [24]; Ceccato and Basso [32]; Fagundes et al. [21]; Garrone, Melacini and Perego [36]; Halloran et al. [37]
Packaging (standard and organized in packages, boxes)	Transport, storage, warehousing, commercialization	Almeida et al. [24]; Ceccato and Basso [32]; Ribeiro et al. [34]; Tofanelli et al. [23]; Fagundes et al. [21]; Lourenço and Katz [18]; Tofanelli et al. [34]

Table 1. *Cont.*

Best Practices	Stage	Authors
Improvement in structure and facilities (refrigerated shelves and chambers)	Transport, storage, warehousing, commercialization	Almeida et al. [24]; Ribeiro et al. [34]; Ceccato and Basso [32]; Fagundes et al. [21]; Tofanelli et al. [23]; Tofanelli et al. [34]; Lourenço and Katz [18]; Questedet al. [38]; Scholz et al. [13]
Demand forecasting (demand pulled) and inventory control	Planting, storage, warehousing, commercialization	Ceccato and Basso [32]; Almeida et al. [24], Tofanelli et al. [23]; Tofanelli et al. [34]; Brandão and Arbage [19]; Prado et al. [39]; Buzby and Hyman [35]; Papargyropoulou et al. [39]; Stefan et al. [40]; Garrone et al. [36]; Betz et al. [41]; Sonnino and McWilliam [42]
Decrease in retail and wholesale prices and other quick selling actions	Commercialization	Tofanelli et al. [33]; Prado et al. [22]; Tofanelli et al. [23]
Integrated logistics and SCM (supplier selection, partnerships, information sharing)	All stages	Brandão and Arbage [19]; Tofanelli et al. [23]; Tofanelli et al. [34]; Ceccato and Basso (2012); Lourenço and Katz [18]; Buzby and Hyman [35]; Papargyropoulou et al. [39]; Stefan et al. [40]; Garrone et al. [36]; Betz et al. [41]; Sonnino and McWilliam [42]; Aschemann-Witzel et al. [43]
Regional Fruit Purchase (nearest suppliers)	Commercialization	Almeida et al. [24]; Ceccato and Basso [32]; Tofanelli et al. [33]
Guidance and training of labor	All stages	Almeida et al. [24]; Lourenço and Katz [18], Ceccato and Basso [32]; Tofanelli et al. [33]; Fagundes et al. [21]
Adoption of processes and processing technology	Processing	Marchetto et al. [44]; Prado et al. [22]; Tofanelli et al. [23]; Tofanelli et al. [34]
Appropriate vehicle and improved road conservation	Transport	Almeida et al. [24]; Ribeiro et al. [34]; Tofanelli et al. [33]; Fagundes et al. [21]; Lourenço and Katz [18]; Ceccato and Basso [32]
Stacking, receiving (inspection and checking), and handling (cargo equipment)	Transport, storage, warehousing, commercialization	Almeida et al. [24]; Lourenço and Katz [18]; Ceccato and Basso [32]; Brandão and Arbage [19]; Prado et al. [22]; Fagundes et al. [21]; Tofanelli et al. [23]; Tofanelli et al. [34]
Maintenance and hygiene of packaging, transport, store, and warehouse	Transport, storage, warehousing, commercialization	Almeida et al. [24]; Ceccato and Basso [32]

Table 1. *Cont.*

Best Practices	Stage	Authors
Education and awareness of the final consumer (manipulation campaigns)	Commercialization	Tofanelli et al. [33]; Prado et al. [22]; Aschemann-Witzel et al. [43]; Byker et al. [14], Stefan et al. [40]; Stancu et al. [11]; Secondi et al. [13]; Parizeau et al. [17]; Visschers et al. [12]
Reuse and disposal of waste	Donation, composting, feed production, food bank	Marchetto et al. [44]; Prado et al. [22]; Belik et al. [20]; Fagundes et al. [21]; Ceccato and Basso [32]; Quested et al. [38]; Visschers et al. [12]; Papargyropoulou et al. [39]

According to Table 1, among the best practices can be highlighted the concerns to improve the quality of food, the extra care to handle fruits and vegetables, the proper packaging and facilities, such as structures with refrigerated chambers and shelves, management of the quantity offered, the information sharing and collaborative partnerships, and the education and awareness of the final consumer.

The main logistical actions to reduce food waste due to deterioration are purchase planning, storing products in air-conditioned environments, appropriate boxes and packaging, correctly exposing products, conducting campaigns with customers to properly handle products, acclimatizing the store, and regulating the store refrigerators and freezers [22]. The authors also proposed actions to avoid losses due to packaging damage: care in unloading and handling products, improving storage, training employees, and reinforcing care in the proper display of products. Some internal and external measures to reduce vegetable losses were pointed out by Tofanelli et al. [23]. The internal ones: improving inventory control, purchase of fresh vegetables, purchase of regional vegetables, decrease in retail prices, care in handling during transportation, prevention of excessive handling by the consumer, and improving the structure of the establishment. The external ones: lower wholesale prices, closer wholesale suppliers, educating the final consumer, enhancing the quality of vegetables, improving packaging, encouraging local vegetable growing, and greater integration and collaboration of members of the agricultural supply chain.

The measures to reduce food waste are cleaning transport, monoblock boxes, and marketing benches; uniformity in the organization of vegetables in boxes; selecting the best times for the outlets; and product offers according to demand [24].

The great majority of studies aim to understand the behavior of the final consumer, listing the factors that drive food waste, considering that some studies point out that, at the consumption stage, there is more generation of food waste and a greater possibility of prevention [11]. However, although consumers appear to make the most significant contribution to the wasted food volume, there is almost no information on the drivers of such behavior in consumer households [40]. In this sense, the minimization of food residues in developed countries should be focused on the retail and consumption stages [39]. The waste of consumer-related food is a complex issue requiring collaboration among various actors in the supply chain and actions to increase awareness [43].

3. Research Techniques

This research is characterized as applied, descriptive, and exploratory and uses a qualitative approach. We conducted a systematic literature review and a multiple case study. Table 2 shows the technical procedures adopted and their respective research instruments to collect data. The study was divided into two stages and related technical procedures. The first phase covered two systematic literature reviews, and the second one the multiple case study.

Table 2. Relation between technical procedures and data collection instruments.

	Procedure	Data Collection Instrument	Source
1st phase	Systematic literature review (Brazilian literature)	Documental analysis	Cronin et al. [45]
	Systematic literature review (international literature)	Documental analysis	Pagani et al. [46]
2nd phase	Case study (multiple cases)	Semi-structured interviews and direct observation	Yin [47]

We carried out two systematic literature reviews to demonstrate state of the art on food losses and waste. In addition to summarizing the main problems throughout the agri-food supply chain, the review pointed out solutions through the implementation of best practices. Two different protocols were used to carry out the systematic literature reviews: (i) the Brazilian one used the protocol from Cronin et al. [45] and (ii) the international one used the protocol from Pagani et al. [46]. Two procedures were necessary considering that the Brazilian journals, at most, do not have impact factor information, which would be required to calculate the InOrdinatio Index proposed by Pagani et al. [46]. Thus, the protocol from Cronin et al. [45] was used. To summarize, the first three steps were the same in both protocols; they differed in terms of the filtering process, because the Methodi Ordination uses the InOrdination as an additional step of filtering.

The Brazilian literature analysis followed the protocol of Cronin et al. [45], with the following steps: (a) research question formulation; (b) set of inclusion and exclusion criteria; (c) selection and access to literature; (d) quality evaluation of the literature included in the review; and (e) result analysis, synthesis, and dissemination. From the keywords food waste OR food losses, in the Portuguese language, 15,100 results were found on the Google academics platform in order of relevance. The titles and keywords of the first 400 links were selected and evaluated. Due to the filtering process, 78 were eliminated. In addition, 310 were excluded due to inconsistency with the scope of the study. After reading the abstracts, 12 articles were thoroughly analyzed.

In the systematic international review, the Methodi InOrdinatio was used to classify the quality of the articles [46]. The method allowed us to select the best articles by ordering the highest scores. The calculation considers the publication year, the impact factor of the journal, and the number of citations. Pagani et al. [46] advise the researcher to determine the cutoff line so that only the articles above the line are read in full. Thus, 17 articles were selected, which presented an InOrdinatio superior to 123. At first, 437 articles were found, considering the same keywords in the English language. The studies were analyzed by reading the titles and abstracts. Of the 437 articles, 358 were excluded due to inconsistency with the theme. The remaining 79 articles passed through the Methodi Ordinatio filter, which calculates an index called InOrdinatio to rank the papers considering the number of citations, year of publication, and impact factor, leaving, in the end, 17 articles higher than the cutoff line of 123 points of InOrdinatio. Thus, the final systematic review included 29 articles—12 Brazilian and 17 international papers. Figure 1 presents the results of the two SLRs. It is important to emphasize that this procedure supported the questionnaire elaboration applied with the sample of participants of the study.

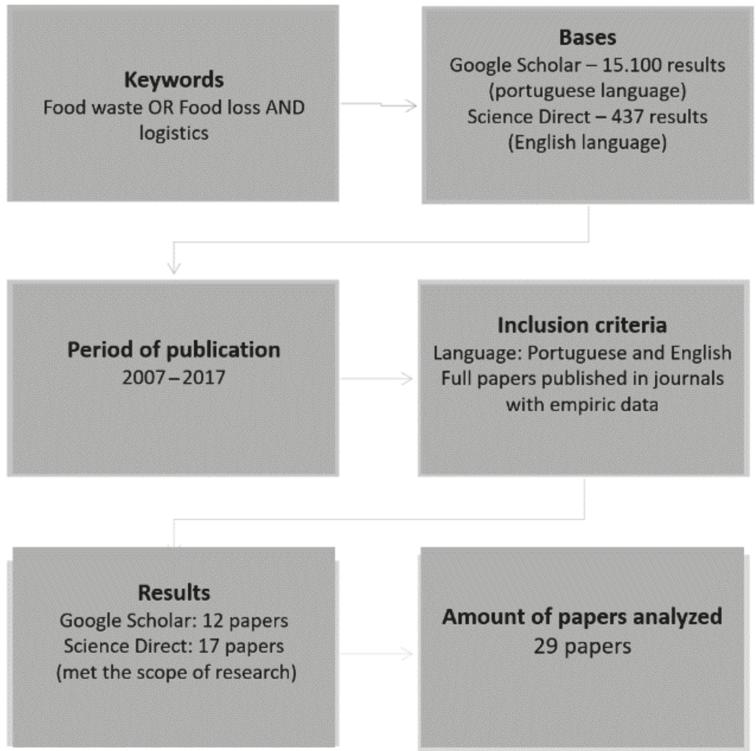

Figure 1. Protocol to select and filter papers analyzed in the SLR.

For this reason, the SLR considered just papers published until 2017. We understand that this is a limitation of this study. Further studies can confirm the logistic practices from 2018 to the future.

Regarding the second phase of the research, the study of multiple cases was carried out mainly through semi-structured interviews and by the direct observation "in loco" in the stores of fruits and vegetables located in the Federal District and wholesaler storages, with the professionals responsible for the fruit and vegetable commercialization (owners and managers), involving retailers and wholesalers in the Federal District, Brazil. The study was carried out at Ceasa/DF, the center of food distribution (wholesale) and local retailers, located in the following administrative regions of the Federal District: Samambaia, Taguatinga, Ceilândia, Guará, and Asa Norte. The interviews were conducted in person, at the establishments, without an appointment by occasional visits, with an average duration of 25 min. The interviews were carried out from 2019 to 2020 and recorded with the authorization of the interviewees to allow the transcription for further interpretation and analysis.

Nineteen fruit and vegetable retailers and eight wholesalers from the CEASA-DF were part of this analysis. It is noted that a sample was not established a priori, being followed by the theoretical saturation technique. Regarding the size of wholesale establishments, 37.5% were large companies, and the remainder were small ones. Of the retailers surveyed, 16% were individual microentrepreneurs, 53% were microenterprises, 21% were small, and 10% represented large companies. Regarding the profile of the interviewees, 53% were the owners of the establishments, 26% were managers, 16% were replenishment managers and, 5% were sales managers. Table 3 shows the characteristics of the study participants.

Table 3. Characterization of participants of the study.

Id	Place (AR)	Size of Company	Participant	Id	Place (AR)	Size	Participant
E1	Samambaia	Micro	Owner	**E11**	Ceilândia	Micro	Owner
E2	Samambaia	Micro	Owner	**E12**	Guará	Micro	General manager
E3	Samambaia	Individual microentre-preneur	Owner	**E13**	Guará	Micro	Owner
E4	Samambaia	Micro	Owner	**E14**	Guará	Micro	Replenishment manager
E5	Samambaia	Small	General Manager	**E15**	Guará	Larger	Replenishment manager
E6	Taguatinga	Small	General Manager	**E16**	Guará	Micro	Owner
E7	Taguatinga	Micro	General Manager	**E17**	Asa Norte	Micro	Replenishment manager
E8	Taguatinga	Individual microentre-preneur	Owner	**E18**	Asa Norte	Larger	Supply manager
E9	Taguatinga	Individual microentre-preneur	Owner	**E19**	Asa Norte	Small	Owner
E10	Ceilância	Small	Sales manager				

According to Table 3, 19 companies were part of this analysis, representing the retail sector of fruits and vegetables, 26% located in Samambaia, 21% in Taguatinga, 11% in Ceilândia, 27% in Guará, and 15% in Asa Norte. The companies were found in searches conducted on the Google Maps tool, based on the search for keywords in Portuguese: "Verdurão," "sacolão," "frutaria," and "Hortifruti," which are terms used to refer to retailers specialized in fruits and vegetables in Brazil. Thirty-six establishments were found, of which six were no longer in operation, four did not accept to participate in the study, and the other seven were not accessible—four due to their location and the remaining three because they belong to foreigners who are not able to communicate in Portuguese—preventing the conduction of the interviews. Therefore, the choice of the participating companies followed the criteria of accessibility (the managers/owners should agree to participate) and representativeness (the companies should meet the search criteria).

A semi-structured interview script, designed on the basis of the systematic literature reviews, was used for data collection. The script went through analysis by judges to give more robustness to the items. The judges were seven teachers with an affinity to the themes of logistics and agribusiness. The questions were analyzed for the criteria of intelligibility, clarity of information, and coherence of terms, considering the pre-established objectives. The script was composed of four categories: Handling; Conservation and Maintenance; Control and Logistics Management, and Awareness. In total, 23 questions were added, with six items on the first category, seven items on the second category, nine items on the third category, and one item on category 4.

We conducted a thematic categorial content analysis technique to analyze the results, following the protocol proposed by Bardin [48]: pre-analysis; exploration of the material; and treatment of the results, inference, and interpretation. We detailed the results in categories that are analyzed under the thematic content of the interviews and documental analysis, enabling the identification of the meaning in the interview composition. The categories established a priori were as follows: (a) handling, (b) conservation and maintenance, (c) control and logistical management, (d) awareness.

4. Results and Discussion

Table 4 presents the main obtained results from interviews and direct observation for the categories handling, conservation, management and control, and awareness for the local retailers and wholesalers of fruits and vegetables considered in this study.

Table 4. Main results of the case studies.

Category	Main Results	Retailer	Wholesaler
Handling	The loads originate primarily from the Northeast and Southeast regions		X
	Manual or trolley unloading makes work easier and reducing impact injuries	X	X
	The conference of loads, regarding quantity (weight), quality (uniformity, maturation, presence of imperfections)	X	X
	The storage process involves stacking and removing excess merchandise from the edges	X	
	High waste due to consumer handling	X	
	Consumers are well advised on the correct handling		X
	The most significant waste due to handling comes from the consumer squeezing and kneading the fruits and vegetables	X	
Conservation	There are cold chambers for the fruit and vegetable storage which, prolongs durability and reduces waste		X
	The durability of items that are refrigerated is noticeably increased, reducing waste	X	X
	The use of packaging in the commercialization environment preserves and protects the food	X	
	The conservation of fruits and vegetables in transport requires the use of correct packaging to prevent abrasion		X
	The fleet used to transport cargo is varied and not refrigerated in most establishments	X	X
	CEASA requires the use of correct material for packaging and transportation: plastic boxes		X
	Hygienization and pest control have an impact on the durability of FVLs about the removal of insects	X	X
	Damaged products are removed to avoid the degrading agents from spreading	X	
	The use of damaged and imperfect products occurs through processing for internal consumption	X	

Table 4. *Cont.*

Category	Main Results	Retailer	Wholesaler
Management and control	Absence of purchase planning	X	X
	Excessive purchases generate waste		X
	The cost spent, the time dedicated, and the refusal of the owner appear as an obstacle to the adoption of inventory management tools	X	X
	Strategies to increase turnover revolve around high-end offers, a single-price offer, and the establishment of a day to promote FVLs	X	
	Strategies for selling imperfect items revolve around negotiation with suppliers, selling to regions with lower purchasing power, and selling to establishments that process FVLs		X
	There are no measures to reduce the distance between retail and wholesale/wholesale and producer	X	X
	Information about demand forecasting takes place in a short period, not providing other members with a planning option	X	X
	Waste reduction is achieved through donations made to needy individuals and institutions	X	X
	The difficulty in donating food is related to the cost of transport to the beneficiary	X	
	A solid-waste company does disposal	X	X
	Disposal is done in the common garbage for collection by the urban cleaning service	X	
	Farm owners collect food residues for animal feed and soil fertilization	X	
	Lack of training for employees and awareness of owners about the problem of waste	X	X
Awareness	It has campaigns or information about education and awareness of the final consumer regarding the correct handling and domestic planning		

The handling category identified the receiving, storage, warehouse, and commercialization practices (Table 4). As soon as the trucks arrive at the retail establishment, manual unloading or unloading with the aid of trolleys and pallet trucks is made, which facilitates handling work and reduces injuries due to impact, upon receiving the cargo, checking what is being received stands out regarding the quantity (weight) and the products' quality (uniformity, degree of maturation, and presentation of injuries or imperfections). The storage and warehousing processes involve stacking the boxes, removing at first the excess of goods at the edges of the boxes.

In 40% of the establishments that have storage for the fruits and vegetables, there are no cold rooms to store them, which reduces their durability. All establishments reported having significant waste due to excessive and incorrect handling by the final consumer (e.g., kneading and squeezing food). However, 27% of establishments did not advise consumers on the correct handling of fruits and vegetables to avoid embarrassment.

The conservation category identified the practices of conservation, maintenance/hygiene, organization, and separation of food. The increase in durability and the preservation of the quality of the exposed items under refrigeration stood out, which considerably reduces waste. The use of packaging is essential for the conservation of fruits and vegetables, which suffer effects related to the transport itself and the sales environment, and the effects of excessive handling. In turn, sanitation impacts the durability of fruits and vegetables concerning the removal of insects.

The shelves' organization is relevant in terms of separation by type and group of products. Damaged fruits and vegetables are removed when the shelf is replenished and throughout the day to avoid the spread of degrading agents. Products considered imperfect, outside the aesthetic standards required by customers, are removed from the shelves or are not exposed. Then, they are directed to the employees' consumers, avoiding waste—some establishments process these imperfect products for sale as fruit pulps, soup preparations, fruit salad, and natural juices.

The management and control category identified practices related to demand forecasting and the use of inventory management tools, a strategy to increase product turnover, and measures to reduce the distance between retail and supplier, in addition to the reverse logistics of waste and imperfect food. The results showed the absence of purchase planning and predictions made through notes and lists without strategic planning to reduce waste. Excessive purchases generated waste of fruits and vegetables even for establishments that make daily purchases. It was noted that the adoption of information technology tools for the planning of purchases did not occur due to the cost, the spent time, and the owner's refusal.

The strategies to increase the product turnover revolved around promotions (for example, Green Tuesday and Green Wednesday) and the offer of a single price, the so-called *sacolão*. The practice of *sacolão* has become unfeasible due to price discrepancies and the variety of products offered. We observed that there was little exchange of information between retailers and wholesalers about the demand forecast. As a result, the wholesaler's planning was also affected. Negotiation with suppliers of items with minor imperfections was a possibility given waste mitigation strategies. The reduction of waste also occurred through the use of foods that were still within the expected nutritional level but were no longer considered within the standards of retail marketing because they contained some imperfection or are damaged in some parts.

Regarding the possibility of food donation, there was difficulty due to the cost of transporting the products to the entity to be benefited. Food unfit for human consumption was used for animal feed or compost production or was discarded in the garbage for collection by the urban cleaning service. Regarding the awareness category, none of the retail establishments had awareness campaigns for the final consumer. The impediments revolved around the costs and spent time. Moreover, retailers pointed out that they had never been approached by the private sector or government institutions for presentation and incentives for initiatives in this regard.

Regarding the study carried out with wholesalers, three categories were established. The first was about handling the receiving, storage, and marketing stages. The results show that about 50% of the food sold came from the northeast and southeast regions of the country, 25% from the south, and 12.5% from the central-west region. In companies that work with imported products, about 12.5% came from Argentina and Chile. Regarding the unloading process of the trucks, the loads were received, weighed, and taken into the box. During the receipt of the products, the employees responsible for checking the loads evaluated the temperature, uniformity, degree of maturity, and quality of the received food. Regarding batch uniformity, fruit sizes were checked, standardization was always prioritized, and the most presentable items were separated from imperfect ones. The cold chambers located inside the box were used so that the fruits were packaged and had prolonged durability and a visible reduction of waste.

The second category was the conservation, maintenance/hygiene, and separation of damaged or imperfect items. In terms of conservation in the commercial environment, we highlight the establishments that used cold rooms. It is noteworthy that CEASA stipulates that permit holders use correct packaging without using wooden boxes. However, the use of these is still being verified. The issue of transporting cargo over long distances was one of the factors to be analyzed since conservation requires refrigerated box trucks. However, the fleet varied widely between open bodies, closed box trucks, and refrigerated box trucks.

Regarding the maintenance and hygiene of the commercialization environments, the licensees cleaned the box and washed the containers frequently. Regarding the use of insecticides for the removal of insects, the licensees informed us that CEASA was responsible for environmental pest control. Concerning removing damaged or imperfect products, the interviewees aimed to remove damaged products and discard them so that they did not damage the cargo. For defective items, just as in retail, price offers were the first choice. Another mentioned option was sale to establishments that would process this food, such as snack bars and restaurants.

Furthermore, the third category referred to demand forecasting and the use of inventory management tools, a strategy to increase product turnover, the relationship between retail and supplier, and CEASA's role in terms of waste and reverse logistic waste and imperfect food. Wholesalers who used a management system that assisted in planning the purchase had difficulty interpreting the information. This highlights the importance of training and development of employees, not only regarding correct handling but also with respect to feeding information systems. It should be noted that the large stocks held were responsible for a large part of the waste at the supply terminals. To increase the turnover of products, the sale of products to the "sacolão" was pointed out, the negotiation of a lower price with the producer, the search for customers and the guarantee that they work with a quality product.

It was noticed that the wholesaler link, the permit holders of CEASA-DF, usually exchanged price information and the quality of the products with the producer. The information exchanged between retail and wholesale revolved around the requirements of retailers concerning quality, price, delivery time, and merchandise exchanges. There was no sharing of strategic information among members about forecasting demand or stock level to reduce waste. Respondents pointed to the zero-waste program as the initiative to reduce waste. In addition to sending damaged and imperfect food to CEASA-Federal District's zero-waste program, respondents reported making donations to entities such as daycare centers, churches, non-governmental organizations (NGOs), and SESC (Social Service of Commerce). There was no waste reuse program for composting or producing animal feed. There was still much waste at CEASA-DF due to the lack of awareness and involvement of permit holders in waste reduction practices. Some studies deal with solutions to improve food donations from restaurants to the food-insecure population using modeling [49], which can be pointed out as a positive effort involving the storage, collection, and transportation logistical activities to reduce food waste.

5. Conclusions

This study dealt with the analysis of good logistical practices in reducing fruit and vegetable waste in retail and wholesale companies, as these marketing links comprise stages in the supply chain with a high percentage of waste. To provide a broad and diversified panorama and to get inputs for the elaboration of the questionnaires to collect data, a systematic national and international review was carried out, which supported the item's construction of the semi-structured script used in the interviews in the study of multiple cases, which is the central part of this study.

Given the obtained results, the need to make consumers aware of the correct handling of fruits and vegetables in retail establishments is highlighted. In addition, we emphasize the requirement for the companies to carry out campaigns with public–private partnerships to educate the consumer, either in terms of purchase planning as in the full use of food.

Regarding the wastes that still occur in CEASA-DF, measures to raise the awareness and involvement of permit holders must be adopted, as well as the development of facilities for processing the fruit and vegetables that end up being discarded in containers and destined for landfills.

The research has several contributions. Academically, considering the importance of studying the proposed theme in depth, the research contributes to a more significant discussion about food waste and the investigation of the phenomenon in the retail and wholesale environment. Specifically, the research contributed to the panorama of the national and international state of the art about the good practices carried out along the agricultural supply chain. Furthermore, the logistical practices adopted by two links in the agri-food chain, retailers and wholesalers, were identified to reduce food waste.

From a managerial point of view, the study contributes to retail establishments creating employees and consumers awareness campaigns as to the problems caused by excessive and inadequate handling in the receiving, storage, and marketing stages, contributing to the structuring of marketing processes. As well as in identifying the variables necessary for the maintenance and conservation of fruits and vegetables concerning investment in refrigerated facilities and structures. Our study highlights the relevance of the partnership of retail and wholesale companies with associations that aim at waste reduction. From contributions to the public policy formation, this research points out flaws in the integrated management of the chain, about the adoption of collaborative partnership relationships, information sharing, and lasting partnerships. It leads to several opportunities for creating policies that aim to educate the end consumer about proper handling, planning domestic consumption, making full use of food and conservation, and creating tax incentives to expand the cold chain along the production chain for perishable foods. In general, we expect that this research's results will encourage the adoption of good practices that reduce food waste as a whole minimizing economic, social, and environmental impacts.

Furthermore, we should point out some limitations of the research. The first was the failure to use the same protocol for selecting and filtering papers in the national and international systematic literature reviews. The Methodi Ordinatio, proposed by Pagani et al. [46], was used only in the international review since national journals did not have the impact factor. Regarding the empirical phase of the research, related to case studies, the type of retailer studied was limited to grocery stores and fruit shops. The type of food studied covered only the category of fruits and vegetables, which excludes all the other types of food waste. We also considered the food waste generated in the logistics processes and not that after consumption.

Considering the limitations, some suggestions for future research are proposed. The first is to conduct a more comprehensive systematic literature review, following a harmonized protocol. It would also be interesting to study food waste in other retail links, such as supermarkets of different sizes, restaurants, and after the consumption phase. Further studies can focus on other types of food waste, such as non-perishable and industrialized foods. Additionally, future studies may cover the entire agri-food supply chain, including the logistics processes occurring in the suppliers and the production, the waste in the consumption stage, and the final consumers' role.

Further studies can approach the modeling approach from operational research to propose, for example, a volunteer-based crowd-shipping program for food rescue, considering the restaurant's food donation delivery as proposed by Mittal et al. [49]. Similar modeling can be conducted in the case of wholesaler donations. In addition to that, other models can use modeling from the multicriteria decision aid approach to optimize food donation, helping food-insecure people.

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Transparency in Global Agribusiness: Transforming Brazil's Soybean Supply Chain Based on Companies' Accountability

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Abstract: *Background:* Although agri-food supply chains have become fundamental for food security throughout the world, some are associated with negative environmental and socioeconomic impacts. This study explores the possibilities of transforming the governance in Brazil's soybean supply chain based on stakeholders' accountability. *Methods:* We used secondary data from companies' reports and statistical yearbooks to identify key stakeholders in the soybean supply chain as well as to explore trade-offs between reducing farming expansion into new agricultural frontiers and increasing investments in agro-industrial sectors. *Results:* The results reveal that at the global level, multinational corporations along with domestic groups should be held accountable for improving the governance of the soybean supply chain in Brazil since foreign multinationals control 65.4% of it. At the domestic level, losses in Brazil's farming sector can either be offset by an 11% or 5.2% market share increase in the trading segment or in the whole supply chain, respectively, since Brazilian groups control 93.4% of the farming sector but only 7.1% of the agro-industrial sectors. *Conclusions:* Global accountability and domestic trade-offs are fundamental for transforming governance in global agri-food supply chains. They serve as a means for overcoming the current strategy of expansion into new farming frontiers.

Keywords: food supply chains transformation; stakeholder accountability; business evolution; corporate environmental management; responses to environmental issues; environmental; social and governance values (ESG)

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1. Introduction

There is growing global interest in the transparency and sustainability of agri-food supply chains [1,2]. Improved relationship strategies in food supply chains (e.g., cooperation, coordination, and collaboration and accountability) can generate positive effects such sustainable gains in environmental and economic dimensions [3].

As some agri-food supply chains are largely international, making them more accountable and sustainable requires a collaborative effort among different countries and stakeholders [4]. Approaches toward sustainable and responsible agri-food supply chains, therefore, need to be promoted in different business sectors that include all the key stakeholders established along the supply chain [5–7].

There is a growing demand for transparency at the international market level over how supply chains source agricultural commodities [8]. As a practical outcome of flaws in transparency, part of the agricultural global flows remains unaccountable, which is detrimental to the agri-food sector as a whole.

Corporate sustainability as a business response to environmental issues requires improved transparency, governance, and accountability across the supply chain as a whole [7]. The existing top-down approaches such as market moratoriums [9], reductions in foreign direct investments [10], and commitments to eliminate deforestation from agricultural commodity chains [11] put pressure on domestic and multinational groups operating in the farming and trading sectors. However, by focusing on output segments, these approaches do not hold accountable the important multinational corporations involved in the input segments, such as seeds, machinery, agrochemicals, and fertilisers [8,12].

These approaches also offer no trade-offs between reducing domestic investments in farming expansion into new agricultural frontiers and increasing them in agro-industrial sectors such as seeds, machinery, fertilisers, agrochemicals, and trading. The opportunity costs of reducing the expansion of agricultural frontiers can be offset by investments in industrial segments that better remunerate capital and labour [12]. As a consequence, important stakeholders lack accountability in these current approaches to improve governance [13].

To improve the accountability in supply chains, those who will be sharing the costs for better practices, and the possible trade-offs for committed stakeholders, must be identified. There are two fundamental steps required to make this happen. First, the key stakeholders that need to be accountable in the process must be identified for the sake of transparency. Second, possible win-win solutions and trade-offs for addressing the existing challenges should be explored [14]. To this end, it is fundamental to have a comprehensive understanding of agri-food supply chains as a whole, as well as the market share held by key stakeholders.

This article adds to existing efforts to improve transparency in the soybean supply chain established in Brazil as a means to transform governance based on the accountability of companies and possible trade-offs for committed stakeholders. This can lead to future renegotiations of responsibilities targeting the development of fair, responsible, and sustainable agri-food supply chains.

This article specifically aims to identify the key stakeholders operating in the supply chain and their respective market shares as a means to discuss their accountability in the business. Further, it explores trade-offs between reducing the domestic investments in farming expansion and increasing the market share in agro-industrial segments that better remunerate capital and labour. By doing so, this study explores a novel conceptualisation of food supply chain transformations that can lead to greater benefits for different countries and stakeholders.

2. Theoretical Framework

2.1. Soybean Agribusiness

Soybean is the main crop in Brazil, both in scale and in value. In the 1990s, soybean advanced from the south towards the central area of Brazil, and in the 2000s, it expanded farther to the north [15]. Soybean monoculture is now expanding towards new agricultural frontiers such as parts of the Amazon and the Matopiba (Matopiba is a new agricultural frontier in Brazil that partially covers the states of Maranhão, Tocantins, Piauí, and Bahia) in the north and northeast of Brazil, respectively, as represented in Figure 1.

Brazilian environmental law and the forest code disciplines agricultural expansion into areas of native forests but the growing markets for soybeans drive farmers' expansion towards new agricultural frontiers [16]. Part of the commodity-exporting farming sector strategy has been to laterally expand production into these new agricultural frontiers, particularly by reducing the so-called "Brazil cost" (transaction costs of producing and commercialising in Brazil), through the improvement of infrastructure (i.e., roads, storage conditions, railway construction, and improvements in ports) [17].

The most common implications from the expansion of the commodity-exporting farm sector in Brazil are land related conflicts [18] and the increase in deforestation rates [19]. Most commonly, land related conflicts happen when the local population, who are considered informal land holders (the so-called posseiros) are faced with immigrating large-scale farmers in search of new land to be farmed. There here are also similar cases of large-scale farmers invading traditional indigenous lands that are still not acknowledged by the government [20].

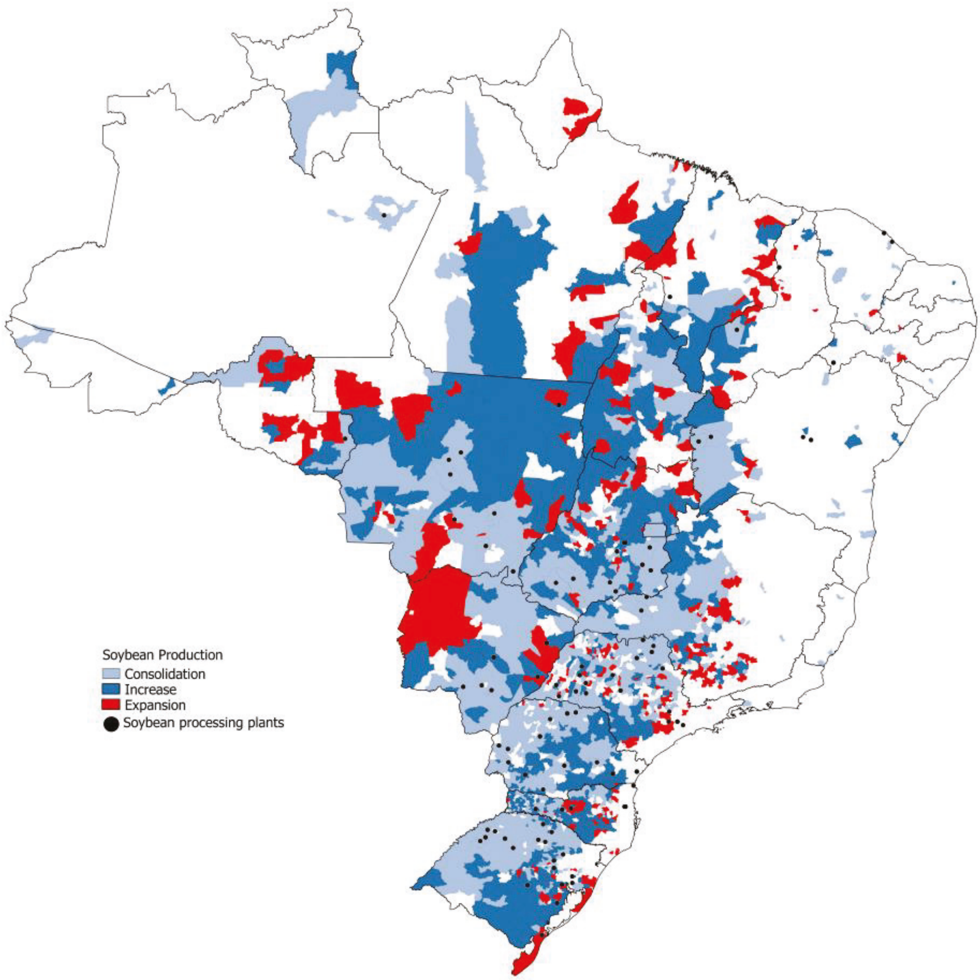

Figure 1. Consolidation and expansion of soy plantations in Brazil between 2006 and 2017. Consolidation is defined as municipalities that have remained as important producers and that have increased their planted areas, when comparing data from 2017 with 2006. Expansion is defined as municipalities planted with soy in 2017 that did not previously have soy planted in 2006. Source: Based on the data of the area planted with soybeans in 2006 and 2017, which are available at the Brazilian Institute for Geography and Statistics website (SIDRA/IBGE). 2017 is the year of the latest agricultural census in Brazil.

The expansion of the agricultural frontier has been causing relevant environmental impacts, particularly the deforestation of native forests. Farming expansion is one of the main causes of deforestation in the Amazon [21] and soybean expansion into the Matopiba region is taking place in the states with the greatest percentage of native vegetation of the Cerrado biome [17].

The growing demand for transparency at the international market level over how supply chains source agricultural commodities has resulted in important practical measures for curbing deforestation. Initiatives led by importing countries include the Amsterdam Declaration, a commitment by seven European countries to eliminate deforestation from agricultural commodity chains [11]. Brazil's Soy Moratorium was the first voluntary zero-deforestation agreement implemented by major soybean traders agreeing not to purchase soy grown on deforested lands [9]. Recently, these efforts have also been underpinned by investors threatening to withdraw investments from companies connected to deforestation in the Amazon [10].

Initiatives toward sustainable supply chains focus on the traceability of goods produced by stakeholders established at chains (mainly farmers, soybean crushing plants, and traders). These stakeholders try to collaborate with members that are willing to adapt their practices to new market demands toward a free deforestation supply chain, as described in [7]. Even though progress has been made through these efforts, non-committed sectors maintain their business-as-usual practices by accessing less restrictive markets or leaking farming activities to other agricultural frontiers, such as the Cerrado Brazilian Savannah [11,16,21].

While only six large soy traders account for most soy exports from Brazil, soy businesses involve thousands of companies who may have different deforestation footprints, and must independently comply with any voluntary moratoriums [22]. Although most of Brazil's agricultural output is deforestation-free, 2% of properties in the Amazon and Cerrado are responsible for 62% of all potentially illegal deforestation and roughly 20% of soy exports from both biomes to the EU may be contaminated with illegal deforestation [23]. These studies reveal the importance of targeting key market leading companies but also the need for considering the whole supply chain as a means for improving transparency and accountability [22,23].

2.2. Agribusiness Companies' Accountability

Since the advent of the theoretical framework about the organisation–environment interface demonstrating that no business is an island, scholars have developed intersectoral analytical approaches involving whole supply chains [24]. Specifically in agri-food, supply chains include the farming sector, and the total sum of operations involved in the manufacture and distribution of farm supplies; the production operations of the farm; and the storage, processing, and distribution of farm commodities made from them [25].

Thus, firms are seen as no longer competing only as independent units, but also as members of supply chains or networks, connected to one another to organise and provide a product or service [26]. In this perspective, agri-food supply chains developed the ability to integrate themselves into a chain as a strategy to succeed, creating internal governances in order to increase coopetition [3]. Several challenges and opportunities arise from taking part in a supply chain that forces firms to look for more effective forms of coordinating flows, inside and outside the focal firm [27].

Considering agricultural and agro-industrial practices, new concerns have emerged [7], specifically in areas of the environment [12], transparency [8], and sustainability [28]. Therefore, the development of sustainable food supply chains has gained prominence in recent years [5], with special attention for local characteristics [1] and ecological, environmental, and social dimensions [3].

Through a food supply chain, stakeholders are characterised by interdependence [29]. Scholars sustain that beyond the interdependence based on economic behaviour and through the convergence of goals and needs, the stakeholders' interaction and behaviour do not represent a disconnection from the scenario of social, cultural, and environmental reality, but are also situated on those [3]. The supply chain approach compose new frames that demand a new governance arrangement [5], and in some cases, a redesign of the food supply chain [30].

New frames create specific demands for specific resources that do not just address economic integration, but also correspond to scenarios that involve ecological, environmental, and social dimensions [29]. It is the case for globalised supply chains [5,31], and with multi-sectorial partnerships, as in the soybean produced in Brazil [8,12].

Thus, actions need to be coordinated and accountable to achieve a goal and determine responsibilities among supply chain stakeholders [7], [31]. A supply chain governance framework helps to better understand managerial issues such as how to select partners, how to go about designing partnership arrangements, and how partnerships can be developed to ensure long-term supply chain sustainability and success [32].

Stakeholders in supply chains create their own internal governance arrangements and a variety of external stakeholders may also seek to influence chain activities and/or outcomes [5]. This means that supply chain governance has a multi-institutional nature [5], besides being multi-sectorial [8,12]. Building on this background, studies on supply chains' governance reinforce the importance of strategic alliances among stakeholders [33] realised in socio-technical arrangements [34].

This comprehensive approach helps us to address the functioning of agri-food supply chains, the role played by key stakeholders, and by exploring improvements in its governance based on stakeholders' accountability and trade-offs. It is also useful for identifying the responsibilities and alliances of different stakeholders particularly in hierarchical structures. Even though it is focused on private firms, it can be complemented by a more comprehensive approach involving other stakeholders such as the state.

3. Methods

Similar to what was conducted in previous studies [8,12], key stakeholders in the soybean supply chain were identified based on the definition of the most popular inputs used in each production stage, their suppliers, and the country of origin of the companies involved. The relevance of each stakeholder was estimated based on their market share in each business segment as described in [35]. Market share information was obtained in the companies' reports as well as in statistical yearbooks from producer associations that annually estimate the market participation of their members in Brazil, as described in Table 1.

Table 1. Segments and sources.

Segments	Organisations
Seeds	Brazilian Association of Soybean Seeds Producers (Abrass)
Fertilisers	National Fertilisers Association (ANDA)
Agrochemicals	Brazilian Association of Generic Pesticides (Aenda)
Machinery	National Manufacturers Association of Motor Vehicles (Anfavea)
Farmers	Soybean Producers Association (Aprosoja)

For market share estimations, we first quantified the total sales in the country for each input per segment (e.g., 5580 soybean combines sold in Brazil in the 2019/20 agricultural year). We then identified the main international and domestic companies operating in each segment (e.g., CNH, John Deere, and AGCO in the case of soybean combines), and their total sales (e.g., 2903 soybean combines by CNH, 2269 by John Deere, and 408 by AGCO). To estimate the total market share of domestic groups in each segment of the supply chains in the sample, we calculated and added the market shares of all Brazilian groups. The results are found in Table 2. Information was collected for the years 2015 and 2020 as a means to measure market share evolution over time.

Trade-offs between reduced domestic investments in the farming sector and the increased market share of domestic groups in the agro-industrial segments were explored. This was performed according to the market size of each soybean supply chain stage, which was estimated based on the literature review. The market size of all studied segments (from seeds to trading) was estimated based on annual market transactions in each segment, as presented in Table 3. From this information, scenarios were projected to offset the opportunity costs of curbing agricultural expansion into the two main agricultural frontiers in Brazil: The Amazon with 4.5 million hectares planted with soybean and the Matopiba region of the Cerrado with 5.7 million hectares planted with soybean.

Table 2. Market share held by Brazilian vis à vis multinational companies in sectors of the soybean supply chain established in Brazil for the years of 2015 and 2020 (in percentage).

				2015		2020					
Segment		**Company**	**Home Country**	**Total**	**Brazil**	**Total**	**Brazil**	**US**	**Germany**	**China**	**Others**
Seeds	Technology	Bayer (Monsanto)	Germany	88.8	0.0	90.0	0.0	0.0	90.0	0.0	0.0
		Pioneer/Corteva	United States	5.8	0.0	6.0	0.0	6.0	0.0	0.0	0.0
		Others	Multinational	5.4	0.0	4.0	0.0	0.0	0.0	0.0	4.0
	Production	GDM and others	Multinational	50.0	0.0	75.0	0.0	6.0	29.0	2.0	38.0
		TMG and others	Brazil	50.0	16.5	25.0	8.7	0.0	16.3	0.0	0.0
		Subtotal		100.0	16.5	100.0	8.7	6.0	67.6	1.0	21.0
Machinery	Tractors	AGCO Massey	United States	25.6	0.0	16.9	0.0	16.9	0.0	0.0	0.0
		AGCO Valtra	United States	22.3	0.0	13.4	0.0	13.4	0.0	0.0	0.0
		CNH Case	Italy	6.4	0.0	9.4	0.0	0.0	0.0	0.0	9.4
		CNH New Holland	Italy	19.3	0.0	23.1	0.0	0.0	0.0	0.0	23.1
		John Deere	United States	22.5	0.0	36.7	0.0	36.7	0.0	0.0	0.0
		Agrale S.A	Brazil	3.8	3.8	0.4	0.4	0.0	0.0	0.0	0.0
	Combines	AGCO Massey	United States	10.3	0.0	6.4	0.0	6.4	0.0	0.0	0.0
		AGCO Valtra	EU	3.2	0.0	0.9	0.0	0.9	0.0	0.0	0.0
		CNH Case	Italy	15.5	0.0	18.5	0.0	0.0	0.0	0.0	18.5
		CNH New Holland	Italy	31.0	0.0	33.5	0.0	0.0	0.0	0.0	33.5
		John Deere	United States	40.0	0.0	40.7	0.0	40.7	0.0	0.0	0.0
		Subtotal		100.0	1.9	100.0	0.2	57.5	0.0	0.0	42.3
Fertilisers	Phosphorus	Vale (now Mosaic)	United States	29.6	29.6	29.7	0.0	29.7	0.0	0.0	0.0
		Anglo American	UK	5.9	0.0	6.7	0.0	0.0	0.0	0.0	6.7
		Others	Brazil/Multinationals	20.6	10.3	19.6	17.5	0.0	0.0	0.0	2.1
		Imported		44.0	0.0	44.0	0.0	7.5	0.0	7.0	29.5
	Potassium	Vale (now Mosaic)	United States	8.0	8.0	5.0	0.0	5.0	0.0	0.0	0.0
		Imported		92.0	0.0	95.0	0.0	0.0	11.4	0.0	83.6
	Manufacture	Yara	Norway	20.5	20.5	25.0	0.0	0.0	0.0	0.0	25.0
		Mosaic/ADM	United States	19.0	19.0	20.0	0.0	20.0	0.0	0.0	0.0
		Dreyfus	France	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0
		Nutrien	Canada	0.0	0.0	10.0	0.0	0.0	0.0	0.0	10.0
		Fertipar	Brazil	17.7	17.7	15.0	15.0	0.0	0.0	0.0	0.0
		Heringer (undergoing judicial recovery)	Brazil (56%)	13.3	7.4	6.0	3.3	0.0	0.0	0.0	2.7
		Regional	Brazil	8.2	8.0	7.0	6.5	0.0	0.0	0.0	0.5
		Outros	Brazil/Multinationals	17.3	8.6	17.0	5.0	0.0	0.0	0.0	12.0
		Subtotal		100.0	33.5	100.0	19.2	20.5	2.9	1.8	55.6
Pesticides		Syngenta/ChemChina	China	21.2	0.0	18.6	0.0	0.0	0.0	18.6	0.0
		Bayer	Germany	15.3	0.0	15.7	0.0	0.0	15.7	0.0	0.0
		Basf	Germany	12.4	0.0	9.2	0.0	0.0	9.2	0.0	0.0
		UPL	India	0.0	0.0	8.9	0.0	0.0	0.0	0.0	8.9
		FMC	United States	7.1	0.0	8.5	0.0	8.5	0.0	0.0	0.0
		Corteva	United States	0.0	0.0	4.0	0.0	4.0	0.0	0.0	0.0
		DuPont	United States	6.5	0.0	4.0	0.0	4.0	0.0	0.0	0.0
		Dow	United States	5.6	0.0	3.0	0.0	3.0	0.0	0.0	0.0
		Others	Multinational	26.6	0.0	22.3	0.0	5.0	3.0	5.0	9.3
		Nortox	Brazil	2.3	2.3	2.7	2.7	0.0	0.0	0.0	0.0
		Ourofino	Brazil	1.0	1.0	2.1	2.1	0.0	0.0	0.0	0.0
		Small companies	Brazil	2.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
		Subtotal		100.0	4.3	100.0	5.8	24.5	27.9	23.6	18.2
Farming		Subtotal		100.0	93.4	100.0	93.4	2.0	0.0	1.0	3.6
Trading		Cargill	United States	12.4	0.0	11.4	0.0	11.4	0.0	0.0	0.0
		Bunge	United States	15.7	0.0	9.4	0.0	9.4	0.0	0.0	0.0
		ADM	United States	10.0	0.0	7.8	0.0	7.8	0.0	0.0	0.0
		Dreyfus	France	5.4	0.0	7.5	0.0	0.0	0.0	0.0	7.5
		Cofco	China	0.0	0.0	3.8	0.0	0.0	0.0	3.8	0.0
		Others	Multinational	25.8	0.0	44.0	0.0	11.0	3.0	15.0	15.0
		Amaggi	Brazil	4.1	44.0	6.6	6.6	0.0	0.0	0.0	0.0
		Coamo	Brazil	4.5	4.5	2.3	2.3	0.0	0.0	0.0	0.0
		Cutrale	Brazil	0.1	0.1	1.7	1.7	0.0	0.0	0.0	0.0
		Bianchini	Brazil	3.5	3.5	1.2	1.2	0.0	0.0	0.0	0.0
		Caramuru	Brazil	2.3	2.3	1.0	1.0	0.0	0.0	0.0	0.0
		Granol	Brazil	3.5	3.5	0.2	0.2	0.0	0.0	0.0	0.0
		Comigo	Brazil	1.7	1.7	0.1	0.1	0.0	0.0	0.0	0.0
		Algar Agro	Brazil	1.7	1.7	0.0	0.0	0.0	0.0	0.0	0.0
		Others	Brazil	9.3	9.3	2.9	2.9	0.0	0.0	0.0	0.0
		Subtotal		100.0	30.7	100.0	16.1	39.6	3.0	18.8	22.5

Source: Based on data published by Anprosem [36], Anda [37], Aenda [38], Anfavea [39] and Aprosoja [40].

Trade-offs between reducing investments in farming expansion and increasing market share in agro-industrial sector were explored for the following scenarios: increased domestic market share in the trading segment and in the whole supply chain. Highlighting the significance of agri-food in 2019, the agri-food sector was responsible for 21.2 % of the

Brazilian gross domestic product (GDP), while the farming sector represented 4.8% of the national GDP [41].

Table 3. Market size of each business segments (in USD billions).

Segment	Market Size in 2020 (in USD Billion)	Proportion of the Whole Market (%)	Source
Seeds	2.0	2.3	BRL 8 billion worth market [36]
Machinery	2.3	2.6	BRL 11 billion worth market, 85% soybean [42]
Fertilisers	4.7	5.4	Soybean represents 47% of Brazil's fertiliser market worth USD 10.2 billion [37] *
Agrochemicals	8.1	9.3	Soybean represents 71% of Brazil's pesticides market worth USD 11.5 billion (Santos & Glass, 2018)
Farming	28.6	32.9	Considering 114.8 tons produced in 2020 [43]
Trading	41.2	47.5	USD 34.7 billion exported plus domestic market [44]
Total	86.9	100	

* Based on raw materials and not on manufactured fertilisers.

4. Results

4.1. Key Stakeholders Based on Market Shares

In Brazil, 91.8% of the soybean cultivated is transgenic and the German multinational Bayer controls 90% of Brazil's transgenic market share. Although Brazil has companies that dominate soy genetics, transgenics are controlled by multinationals that receive royalties from Brazilian companies licensed to use their technology in seed production. Domestic seed producers such as Tropical Melhoramento and Genética (TMG) who have created their own germplasm improvement programmes and pay royalties for the use of transgenics, hold 25% of the market share. Studies show that multinationals that own the characteristics transferred to local germplasm make about 65% of the profit from the final price of soybeans, while the other 35% of the profit is shared between the germplasm developers and seed multipliers [45]. Thus, in the segment of the chain related to the production of seeds, domestic capital would be equivalent to only 8.7% for the agricultural year of 2019/2020 (35% of 25% market share), as described in Table 2.

The machinery sector is a worldwide oligopoly as a result of mergers and acquisitions headed by the following major international groups: John Deere, CNH (holder of the brands Case and New Holland), and AGCO (holder of the brands Massey Ferguson and Valtra). In Brazil, the three companies together control 99.6% of tractor sales and 100% of combine harvester sales [39]. The national capital share for the agricultural year of 2019/2020 was estimated at 0.2% when including the Brazilian company Agrale, see Table 2, which produces tractors rarely used for soybean due to their relatively small size. There is a greater market share of domestic companies in the case of agricultural implements, such as ploughs, scarifiers, limestone spreaders and cultivators, although precise data on market share is not available.

The following two types of companies operate in the fertiliser segment: those that produce raw materials (or simple fertilisers) and those that manufacture formulated fertilisers. Most of the raw material for the fertilisers used in Brazil is imported. In the case of soybeans, phosphorus (44% imported) and potassium (95% imported) are the most commonly used macronutrients [37], since soybeans do not require nitrogen fertilisation and there is little use of micronutrient fertilisation. In Brazil, the Vale Company, controlled by Brazilian groups, used to be the largest producer of phosphorus and the only producer of potassium, a sector that is now controlled by the multinational Mosaic. It is estimated that domestic groups produce 8.7% of the fertilisers consumed in Brazil (17.5% of phosphorus and 0% of potassium), as in Table 2.

In relation to fertiliser manufacturers, the market in Brazil is led by the multinational Yara, with domestic groups holding 29.8% of the market. The Fertipar Group and Heringer (today with 56% of national capital) are the Brazilian companies with the largest participation in the manufacturing of fertilisers in Brazil. The rest of the market is serviced by domestic companies of a regional nature and by multinational groups. Considering an 8.7% national share in the production of raw materials and a 29.8% share in the production of fertilisers, it is estimated that Brazilian participation in the fertiliser market has an average of 19.2%, as shown in Table 2.

In Brazil, 94% of total agrochemical (pesticides) sales refer to the following three classes of products, defined by their purpose: insecticides (33%), herbicides (32%), and fungicides (29%). Soybean farming is the main consumer of agrochemicals in Brazil, accounting for 50% of sales according to the National Union of the Plant Defence Products Industry [46]. There are the following two business segments: products with patents that require innovation, controlled by multinational groups; and generic products, authorised after patent exclusivity periods end, in which the industry with domestic capital still has a stake. In the segment of products with patents, there is ample competition, but few of them have a significant market share. In Brazil, the multinationals control 94.2% of sales, specifically Syngenta/ChemChina (18.6%), Bayer (15.7%), and Basf (9.2%), and other multinational groups with smaller slices. The companies with national capital only make up 5.8% of the total of commercial agrochemicals traded in the country [38]. This percentage is made up of domestic companies such as Nortox and Ourofino, and a group of small businesses.

Brazil has been experiencing changes in the profile of the soybean grower. The private producer is now competing with large national corporations and multinational companies such as Los Grobo, which leases land and manages crops, and Agrinvest, which purchases land for agricultural production. In Brazil, there are 33,200 registered properties belonging to foreigners, occupying 3.8 million hectares [47]. The area used for soybeans in Brazil is around 57.2 million hectares and it has been estimated that 93.4% of this area belongs to Brazilian farmers (see Table 2).

The large multinational export companies such as ADM, Bunge, Cargill, and Dreyfus (known as the ABCD group) have oligopolised the governance of the soybean supply chain [48]. Recently, China celebrated the purchase of Noble Agri (trade) by China National Cereals, Oils, and Foodstuffs Corporation (COFCO) as a way to ensure their presence in 21 countries, including Brazil and Argentina, its two largest soy suppliers. It is estimated that domestic capital controlled about 16.1% of the commercial soybean market in the country in the agricultural year of 2019/2020, less than the 30.7% market share of 2015, as in Table 2. Brazilian groups include Amaggi, Coamo (a cooperative), Cutrale, Bianchini, Granol, Caramuru, and Comigo (a cooperative).

The results reveal that the market share held by Brazilian groups as a whole dropped between 2015 and 2020. In this time span, there were changes in the share held by domestic companies in the segments of seeds (from 16.5 to 8.7%), fertilisers (from 33.5 to 19.2%), pesticides (from 4.3 to 5.8%), machinery (from 1.9 to 0.2%), and in the trading sector (from 30.7 to 16.1%). Proportionally, the market share held by Brazilian groups as a whole dropped from 40% in 2015 to 34.6% in 2019/2020. The share of domestic groups in the capital and technology intensive sectors (excluding the farming sector) dropped from 12.5% in 2015 to 7.1% in 2020.

Figure 2 summarises the market share held by Brazilian vis à vis multinational companies in key sectors of Brazil's soybean supply chain for the agricultural year of 2019/2020. It highlights that key agro-industrial segments (such as seeds, machinery, and pesticides) are controlled mainly by multinational companies.

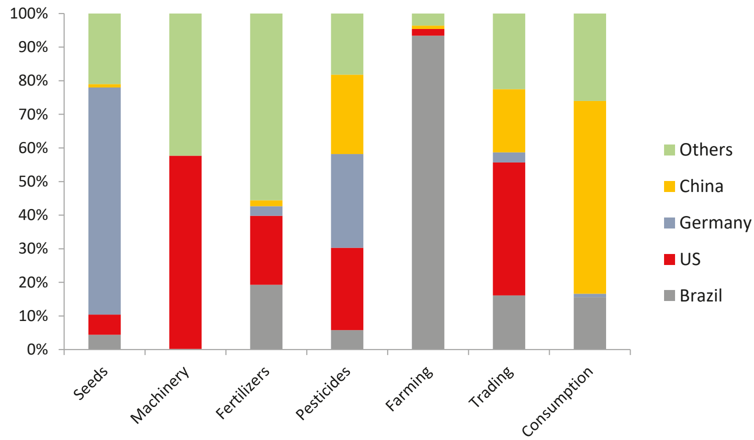

Figure 2. Market share held by Brazilian vis à vis multinational companies in key production stage of the soybean supply chain established in Brazil in 2020 (in %). Source: Based on data published by Anprosem [36], Anda [37], Aenda [38], Anfavea [39] and Aprosoja [40].).

While domestic groups have an important market share in the farming sector, multinational companies tend to control the industrial segments of the production chain. German companies control the seed sector and have an important market share in the pesticides sector. American companies control the machinery sector and have important shares of the pesticides and trading sectors. Chinese companies have a relevant market share in the pesticide and trading sectors, as described in Figure 3. The soybean produced in Brazil is exported mainly to China (57.4%) and domestic consumption in Brazil is the second largest market (15.6%) [48].

Figure 3. Home countries of companies controlling key segments of Brazil's soybean supply chain by 2020. Source: Based on data published by Anprosem [36], Anda [37], Aenda [38], Anfavea [39] and Aprosoja [40].

4.2. Trade-Offs Based on Market Size

The studied segments of the soybean production chain in Brazil generated USD 86.9 billion worth of gross income in the agricultural year of 2019/2020 (see Table 3). The seed segment had a USD 2 billion income, while sales of tractors and combine harvesters resulted in a USD 2.6 billion gross revenue, as described by companies' reports. Fertilisers generated a USD 4.7 billion gross income and the companies in the agrochemicals segment had a gross income of USD 8.1 billion. Estimations were also made for the farming and trading segments that accounted for USD 28.6 billion and USD 41.2 billion worth of markets, respectively [44].

Figure 4 summarises the market size of each segment in the soybean production chain established in Brazil and the market share held by domestic vis à vis multinational companies. It also presents two possible scenarios for trade-offs between reduced farming expansion into new agricultural frontiers and increased market share in agro-industrial sectors. In the first scenario, the opportunity costs of hindered farming expansion are offset by an 11% domestic market share increase in the trading segment. In the second scenario, the opportunity costs are offset by a 5.2% domestic market share increase in the whole supply chain.

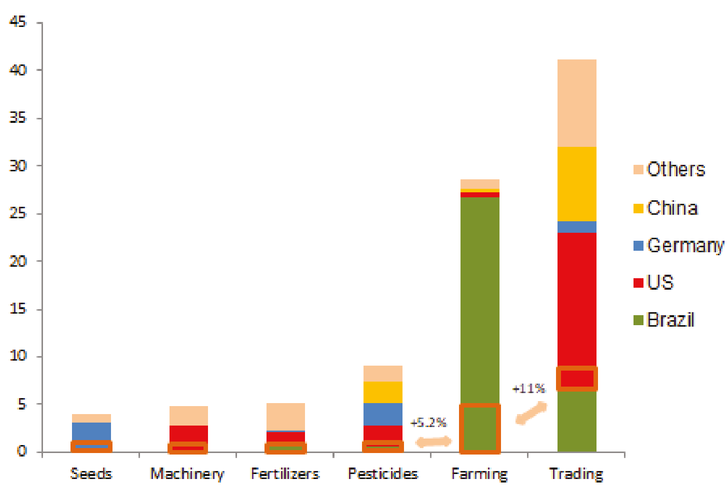

Figure 4. Market size of key segments of the soybean supply chain for the agricultural year of 2019/2020 and possible financial trade-offs between farming expansion and increasing market share in industrial segments (in USD billions). Source: Based on data published by Anprosem [36], Anda [37], Santos and Glass [49] and Escher and Wilkinson [44].

Both scenarios estimate the opportunity costs of stopping the two main agricultural frontiers in Brazil: the Amazon frontier with 4.5 million hectares planted with soybean and the Matopiba region of the Brazilian Savannah (Cerrado) with 5.7 million hectares. Soybean farming generates USD 3.5 billion income per year in the Amazon and USD 4.5 billion per year in the Matopiba, as shown in Table 3.

The results reveal that a USD 4.5 billion gross income in farming activities can either be offset by an 11 or 5.2% domestic market share increase in the trading segment or in the whole supply chain, respectively, as shown in Table 4. In the first scenario, a domestic share in the trading segment equivalent to 27% of the total (the current 16% plus 11%) would be enough for offsetting the income of soybean farms in the Amazon or in the Matopiba region (USD 4.5 billion). In the second scenario, the same outcome can be obtained with a 12.3% domestic market share in the whole soybean production chain (the current 7.1% plus 5.2%). In both cases, the estimated increased market share is smaller than the one held by domestic groups in 2015, that is, 30.7% in the trading segment and 12.5% in the industrial segments.

Table 4. Trade-offs between reducing investments in farming expansion and increasing market share in agro-industrial segments.

	Current Situation		Projection			Outcome
Expansion into agricultural frontiers	Area with soybeans in Brazil (million ha)	Gross income (USD billion)	Measure (Curb deforestation)	Area with soybeans (million ha)	%	Income (USD billion)
Amazon	36.4	28.6	100%	4.5	12.4	3.5
Matopiba	36.4	28.6	100%	5.7	15.7	4.5
Increased market share	Current domestic share	Gross income generated (USD billion)	Measure (increase in domestic market share by)	Targeted market share	%	Income generated (USD billion)
Trading	16.0	41.2	11%	27.0	6.6	4.5
Whole chain	7.1	86.9	5.2%	12.3	6.2	4.5

Source: Based on data published by Anprosem [36], Anda [37], Aenda [38], Anfavea [39] and Aprosoja [40].

5. Discussion

Efforts to promote sustainable and responsible agri-food supply chains have focused on top-down approaches such as market moratoriums [9], reductions in foreign direct investments [10], and commitments to eliminate deforestation from agricultural commodity chains [11]. These measures have proved efficacious in committing the more modern agri-food supply chain to initiatives such as the soy moratorium [9]. However, current efforts still need to address the following two important issues for improved transparency and governance: 1. Make all the stakeholders accountable, including multinational companies and 2. Explore the trade-offs between reduced farming expansion into new agricultural frontiers and domestic investments in agro-industrial segments.

Sectors not committed to improved governance tend to maintain their business-as-usual practices and undermine the whole supply chain reputation [11]. Therefore, top-down enforcement approaches have to be complemented by horizontal efforts to improve accountability in agri-food supply chains. To this end, it is fundamental that supply chains are well understood, and that the roles and responsibilities of key stakeholders are made transparent and, in some cases, renegotiated [50]. It is possible based on a broad picture of the supply chains including the market share held by the key stakeholders.

Corporate sustainability in agri-food supply chains requires improved accountability across the supply chain as a whole [7]. Agri-food supply chains include the farming sector, and the total sum of operations involved in the manufacture and distribution of farm supplies as well as the processing and distribution of farm commodities [3]. Several opportunities, but also responsibilities, arise from taking part in a supply chain [5]. New concerns have emerged in agri-food supply chains [7], specifically in areas of the environment [12], transparency [8], and sustainability [28]. For addressing these issues, recent studies reveal that the supply chains' governance should be based on multi-stakeholder efforts [5,8,12].

This study reveals that multinational corporations are the key stakeholders in the soybean production chain established in Brazil. In all the soybean supply chain agro-industrial segments, multinationals hold the majority of the market share and this foreign control has grown in recent years [49]. Given the hierarchies established in the hybrid forms of governance in supply chains [12], powerful stakeholders such as multinational corporations can play a role in setting up strategic alliances for improved governance [28].

This study also adds to current efforts focusing on the output sectors such as farmers [21] and traders [48] by providing a comprehensive understanding of the whole supply chain including the input sectors (seeds, fertilisers, agrochemicals, and machinery) that should also take part in an improved effort for accountability (see Figure 2). Seeds and pesticides companies have been developing new varieties adapted to new agricultural frontiers prompting conflicts among farmers and among farmers and local communities [51]. Tractors and other machinery are used to introduce plantations in illegally deforested areas [52], and fertilisers make planting soybean in new agricultural frontiers viable [53]. Ultimately, these are business sectors profiting from the expansion of agricultural frontiers [54].

Although the governance is part of companies' strategies for economic performance, in the soybean supply chain case, the existing governance has not avoided negative social and environmental externalities [17]. Therefore, besides the private sector, governments also have a role to play in promoting transparency and supporting sustainable business. As most of the multinational companies are based in wealthy economy countries such as the United States, Germany, and China, these countries should take an active role in promoting the accountability of their home companies operating in developing countries [55].

Local stakeholders including companies, governments, farmers, and local communities can also play a role in improved governance [1]. Domestic groups can explore trade-offs between reducing farming expansion and increasing their market share throughout agro-industrial segments upstream and downstream of farms, as represented in Figure 4. The advances of agri-food production in Brazil offer areas of opportunities for Brazilian groups ranging from strengthening domestic seed-producing companies to the consolidation of regional trading companies. It is by investing in the agro-industrial sectors that will better remunerate capital and labour [56], and going beyond the current focus on the primary production of commodities, that developing countries will benefit from agri-food expansion for their development [57].

To this end, agricultural policy in Brazil needs to evolve from the current almost exclusive focus on subsidised credit (mainly funding or "working" credit for large farmers) to more comprehensive investments that can bring longer-term returns to the agri-food sector as a whole [17]). Rural credit implies the risk of serving only to compensate the low profit margins of farmers who operate in the agri-food supply chains increasingly controlled by multinational groups. As it is now, credits are used by farmers as working capital to buy inputs such as seeds and pesticides from multinationals, which ultimately implies transferring money from Brazilian taxpayers to foreign corporations.

6. Conclusions

This study adds to existing efforts to improve transparency in the soybean supply chain by revealing the key companies operating in each production stage (from seeds to trading) as a means to transform the business based on companies' accountability. The results highlight that all the firms established along the supply chain should be held accountable for improved governance. The efforts for doing so should involve both multinational corporations and domestic groups.

Specifically, this study reveals that multinational corporations established along Brazil's soybean supply chain controls 91.3% of the seed, 99.8% of the machinery, 80.8% of the fertiliser, 94.2% of the agrochemicals, and 83.9% of the trading sectors. German companies control the seeds sector and have an important market share in the agrochemical business. Companies in the US control the machinery sector and have important shares in the agrochemical and trading sectors. Chinese groups have a relevant market share in the agrochemical and trading sectors.

As Brazilian groups control 93.4% of the farming sector, but only 7.1% of the agro-industrial sector, they should explore trade-offs between reducing investments in farming expansion into new agricultural frontiers and increasing their market share in agro-industrial segments. This study reveals two possible trade-offs between reduced farming expansion and increasing the industrial market share. The opportunity costs of hindered farming expansion can be offset either by an 11% domestic market share growth in the trading segment or by a 5.2% domestic market share growth in the whole supply chain. Domestic investments in the agro-industrial segments should be promoted as an alternative to investments in farming expansion into new agricultural frontiers.

These results reveal the need for structural changes as a means to improve governance and corporate sustainability in the soybean supply chain. The necessary improvements include i) increasing the accountability of multinational companies once they are the gearing parts of the soybean agri-food supply chain in Brazil and elsewhere; ii) increasing the market share held by domestic agro-industrial companies in domestic business as a means to promote regional development; iii) discouraging farmer expansion into new agricultural frontiers with high social and environmental costs by replacing the current agricultural policy focused on credit for large farmers through comprehensive investments targeting agri-food supply chains as a whole. By unveiling it, this study highlights the need for a novel conceptualisation of food supply chain transformations that can lead to greater benefits for different countries and stakeholders.

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Review

Food Supply Chain Transformation through Technology and Future Research Directions—A Systematic Review

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Abstract: *Background*: Digital and smart supply chains are reforming the food chain to help eliminate waste, improve food safety, and reduce the possibility of a global food catastrophe. The globe currently faces numerous food-related issues, ranging from a lack of biodiversity to excessive waste, and from ill health caused by excessive consumption to widespread food insecurity. It is time to look back at how technology has tackled food supply-chain challenges related to quality, safety, and sustainability over the last decade. Moreover, continuous transformations of the food supply chain into a more sustainable business model with utmost resilience is the need of the hour due to COVID-19 disruptions. *Method*: This study aimed to systematize literature (2010–2021) in the described context and propose a future research direction, with the assistance of a systematic review and bibliometric analysis on the research agenda proposed above. *Results*: The findings reveal that technological Industry 4.0 (IR 4.0) tools face specific barriers due to the scope and objective of the application. *Conclusion*: The Internet of Things has received more attention than any other IR 4.0 tool. More integration between the specialized tools is needed to address this issue. Furthermore, the authors have proposed a food supply chain-based operational framework on technological inclusion to facilitate the roadmap for food supply chain 4.0 for more resilience and food supply chain viability.

Keywords: food supply transformation; supply chain 4.0; food safety; food quality; food sustainability; COVID-19 disruptions; systematic review

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1. Introduction

The need for food is indicated to quadruple over the next ten years, and the only acceptable alternative is to increase supply without jeopardizing our future. According to the most current UN estimate, there are 7.3 billion people today—and we may reach 9.7 billion by 2050. This expansion, together with rising affluence in developing nations (which generate dietary changes such as eating more protein and meat), is pushing increased global food demand. By 2050, food demand is anticipated to increase by 59 percent to 98 percent. This will shape agricultural markets in unprecedented ways. Farmers worldwide will need to enhance crop production, either by increasing crop production on existing agricultural land or by raising crop productivity on existing agricultural lands through fertilizer and irrigation, as well as adopting innovative methods such as precision farming. However, the environmental and social costs of clearing more land for agriculture are often significant, especially in the tropics. Moreover, crop yields (the number of crops gathered per unit of area cultivated) are currently expanding too slowly to satisfy projected food demand [1]. As a result, farmers' adoption of technology is a critical method for improving agricultural sustainability and production in developing countries [2]. Farm technology, such as remote-controlled harvesting, automated irrigation systems, biometric scanners, drone-based inventory monitoring, and driverless tractors, has made a big difference in recent years. However, the agriculture industry is not as digitally advanced as other industries [3]. Technology can help farmers improve transparency and traceability along their supply chains. Consumers have acquired access to sustainability- and compliance-related information because they are now keen on tracing and tracking the food source they consume [4]. This has further pushed all the stakeholders in the food supply chain (FSC) to create a strong connection between sustainable practices and the food value chain [5].

The Sustainable Development Goals are centered on food systems. The SDGs' broad scope necessitates holistic methodologies that include previously "siloed" food sustainability analyses [6]. All components of food systems must be sustainable, resilient, and efficient in order to provide food and nutrition security for current and future generations. To promote food system sustainability transitions, several measures can be undertaken, including increased efficiency, demand limitation, and food system change. Creating sustainable food systems necessitates shifting from a conventional agriculture-centered policy to a smart food system policy and research paradigm [7]. Sustainability and environmental protection have been in the spotlight. Sustainability is having a significant impact on the global food supply chain, partly because customers desire healthier foods that do not harm the environment [8,9]. Technological tools such as artificial intelligence (AI), Machine Learning (ML), Internet of Things (IoT), Big Data (BD), Digital Twins (DT), Blockchain (BC), and Cyber-Physical Systems (CPS) have leveraged their capabilities greatly to address food supply-chain challenges related to safety, quality, traceability, and sustainability. There is a need to systematize past research endeavors to understand better the trends and future research scope in this context. On that note, this research aimed at conducting an integrated approach of a systematic review and bibliometric analysis that focused on answering the following research questions: What are the current challenges in FSC? What are the technological applications in FSC to overcome those challenges especially during pandemic disruptions? Why is sustainable FSC so important for the future? What are the antecedents of effective relationship management and FSC transformation?

The introduction part of this paper discussed the study's objective, and is followed by the literature review that portrays the trends, applications, and benefits of different technological tools applied in FSC. The keyword selection and article exclusion/inclusion criteria are described in the methodology section, followed by the results section. The dataset was snowballed with systematic and bibliometric analysis to assess the research trend and gaps. Using the insights accumulated from the overall review, the authors have proposed future research directions and barriers in the technological adoption in FSC at the end of this paper before the conclusion.

2. Literature Review

2.1. Rubrics of Food Supply Chain

Food production is divided into four phases. The first stage is locating (local or international) raw materials and verifying their quality and safety standards. Next, after the food is processed, it is sent to the handling and storage stage, where it is cleaned and processed into various end products. The subsequent phase comprises handling and storage, where they are packed according to their specifications before being moved on to distribution and transportation [10]. There are different supply-chain models, such as continuous (cash crops), fast chain (perishable items), efficient (unique products), agile (retail products), flexible (agricultural and meat products) and custom figured (hybrid food items).

Moreover, the global food supply chain is complex and struggles to meet the sustainability and safety benchmark. Therefore, a more robust supply chain structure and market governance are needed to maintain an innovative, sustainable food system. Furthermore, sustainability, availability, financial capital, food safety and security, and traceability are crucial to building a smooth FSC [11].

2.2. Effect of Pandemic Disruptions on Food Supply Chain

The food systems are meeting enormous stress and challenges due to the pandemic disruptions. The world food manufacturers and supply chain providers are now trying to meet that demand by using effective international and domestic trading protocols to stop supply chain resources and bottlenecks [12].

The COVID-19 epidemic has ushered in a new era in the world, with FSC bearing the full brunt. Considering the food supply chain, commercial activities and the supply of various food products have been halted due to a reduction in demand, the closure of food manufacturing facilities, and financial constraints. Farm labor, processing, transportation, and logistics obstacles, as well as significant shifts in demand. The majority of these disruptions are the result of policies implemented to slow the spread of the virus. In the face of these pressures, food supply chains need resilience. Grocery shop shelves are being emptied at a quick pace as stockpiling activity shifts in conjunction with panic buying behavior among customers. Moreover, the greatest threat to food security is not a lack of food, but a lack of consumer access to food [12,13].

Food policymakers are working hard to maintain costs and flows at as minimal a level as possible. The worst-affected section is labor scarcity in food processing and packaging companies, as the industries have been asked to reduce their workforce to stop transmissions. As a result, there are more significant bottlenecks in the FSC [13].

2.3. Conventional Food Supply Chain and Issues

As the world's population grows, so does the need for more food, demanding a more excellent supply of high-quality commodities. On the supply side, however, there is still concern about the industry's ability to fulfill higher product yields and quality improvements as a result of issues such as climate change, droughts, and agricultural productivity. The global agricultural linkages are intricate because they involve numerous actors at various levels, from those who generate and add value to processed goods to those who sell. When there are several distinct food items, each with its own unique and widely fragmented supply chain, the complexity rises. Consumers are increasingly concerned about responsible food sources and food production [14]. FSC management is more difficult in developing countries because they typically involve small-scale farmers with hardly any market governance and outreach. Adverse effects on food availability are generated because of the hurdles faced by FSC, such as substantial intermediation, diminished profitability, decreased quality, food waste, and loss of revenue [15].

Therefore, major players are now motivated to adopt sustainable methods in their supply chains since they can guarantee a consistent food supply and profitability. However, sustainability has a price and workflow to follow. It is one of the major trump cards that can fetch an organization's competitive advantage as per the natural resource-based view. The parameters of successful sustainability directly reduce wastes and improve environmentally green practices (waste reduction), social responsibility (social wellbeing), and economic viability (improved livelihood) [16,17]. It would be interesting to see how technological tools assist in addressing these challenges in FSC.

2.4. Application of Internet of Things (IoT), Big Data & Blockchain in FSC

In underdeveloped countries, only a tiny part of the food supply chain will usually be considered for food ecosystem security audits. The accessibility of the ecosystem, access to the supply chain, and utilization of the food chain are three measurement scales generally used to inspect food and ecosystem security. Food supply networks are complex and interconnected, and IoT-based systems can monitor them to capture details on food materials and protect the ecosystem [18]. The Internet of things (IoT) platform can provide product traceability information in the food supply chain, assisting customers, especially during this pandemic disruption where the information available is so vague. By combining IoT and blockchain technologies, FSC can become more transparent and productive by delivering robust and stable information to clients and related stakeholders [19].

At present, pathogenic and parasitic contaminations can move with frozen food packages, according to scientific evidence, especially in the context of the current COVID-19 situation, where traceability is critical in maintaining food quality and safety. To create a tamperproof audit trail to verify parasites and viruses in packed foods in the FSC, IoT-based, tamperproof data sharing with a centralized architecture and blockchain smart contracts can be used [20]. IoTs can efficiently handle seedling procurement and temperature management in the agriculture industry [21]. Ortañez et al. (2020) [21] built an effective and flexible IoT-based coordinating system for boosting the coordinating mechanism in the agriculture food supply chain during natural outbreaks, to stop the issues caused by fake food. Balamurugan et al. (2021) [22] presented a supplier-based, blockchain hyperledger technology to ensure that FSC data is available and traceable, with an unimpaired substantial computational capacity when implemented within the realms of the IoT [23].

Mondal et al. (2019) [24] presented a distributed ledger technology assisted by IoT architecture, and created a transparent food supply chain using a proof-of-object-based authentication system, similar to cryptocurrency's proof-of-work protocol, coupled with an RFID-connected sensor for real-time data acquisition. As a result, establishing a food traceability supply chain is an effective strategy to address the food safety issue. However, the running costs of a standard food traceability supply chain system are substantial [25]. In an environment where economies are growing more competitive, diversified, and complex, customers have now started to expect high quality and traceability. Blockchain-based software platforms have been advocated to improve traceability by increasing transparency within the FSC [26].

Because of rapid technological advancements, key competitive techniques are rapidly changing. The amount of data globally is continuously increasing; every 12 months, the amount of data in the world doubles [27]. Customers now put too much emphasis on food ingredients and nutritional composition. Even while organic foods are nutritious, they need stringent certification procedures. Big data and blockchain can suffice this issue by providing the necessary certification platform [28].

Li et al. (2017), [29] created a prototype tracking tool that allows the use of sensor data and the creation of data-driven pricing decisions in a variety of operational scenarios and product features. Furthermore, in the same context, Ji et al. (2017), [30] previously introduced a Bayesian network approach for predicting market demand that combines sample data and establishes a cause-and-effect relationship between data, as well as a crisp schematic on how large data can be integrated into Bayesian mathematical network optimization to anticipate demand. Moreover, a service-oriented traceability platform (SOTP) used in the packaged foods supply chain allows real-time dynamic data acquisition and processing of packaged foods information, creating a ubiquitous environment in the packaged foods supply chain. This ensures packaged food's life-cycle visibility and traceability from their production, circulation, and consumption [31]. Additionally, the objective of algorithms for tracing contamination sources and locating potentially contaminated food in markets can be achieved [32].

2.5. Blockchain in FSC

Blockchain is a secure digital ledger that records and validates user transactions that cannot be altered or deleted. These actions are known as blocks, each having its own digital signature and a connection to the previous one. This approach creates a growing list of chronologically arranged encrypted records. Digital currencies or cryptocurrencies are utilized across the supply chain to pay for the quality of assets. Agriculture farmers, distributors, and consumers can pay for selective access, sharing, and authentication of products. The transactions are followed by advanced encryption systems [33,34]. A QR code is placed on food packaging that contains all of the evidence gathered along the supply chain. Consumers may scan the QR code to obtain comprehensive stock traceability, including origin information. Moreover, in global logistics, the distributed ledger technology-based smart contracts (which use the blockchain to execute agreements), and the smart web (cloud) have all been used to preserve container information so that its partners may receive data on container conditions, such as humidity and temperature [34].

Furthermore, this allows banks to also benefit from the FSC's visibility and lend money to farmers without risk. Buyers will have an easier time verifying whether the seller's statements regarding the food quality are accurate through blockchain smart contracts [35]. This technology makes it easier to decentralize, enhance security, sustain and manipulate supply chains during disruptions [33]. Furthermore, a better cost-control mechanism of the food traceability supply chain-based system is also possible to practice [25,26].

2.6. Artificial Intelligence (AI) and Machine Learning (ML) in FSC

AI offers many benefits to the food-processing supply chains. Supply chain players will invest in AI if they foresee long-term revenue gains and other benefits [36]. AI can improve the industry's performance in many ways and add to the gross domestic value. These ways include technical feasibility, intelligence, data quality, and accessibility [37]. Additionally, the food supply chain uses vast amounts of energy. This use significantly affects the environment all along the chain. AI-based optimization can help reduce energy consumption by sharing information, minimizing energy use, optimizing truck routes, reducing greenhouse gas, and shrinking the carbon footprint which is very essential during this pandemic and post pandemic era [38]. Recently, researchers have focused on using AI to help protect supply chains from the effects of disruption. This research suggests that AI can help to improve forecasts and thus mitigate the outcomes of disruptions, an aspect of supply-chain risk management [38]. In recent years, supply-chain risk management has received a lot of attention, intending to protect supply chains from disruptions by forecasting their occurrence and mitigating their negative consequences. Therefore, AI has prompted researchers to look into machine-learning techniques and their application in supply-chain risk management [39].

Food quality is a significant aspect that food engineers keep in mind whilst designing a food system. In tea production, Núñez-Carmona et al. (2021) [40] calculated the volatilome of several tea varieties using metal oxide gas-sensor data and machine learning to provide a competitive tool that can project predictive analysis based on time, costs, and contamination. Moreover, food traceability and shelf life are directly proportional. ML assists blockchain platforms in building anticounterfeiting solid technology in FSC, overcoming drawbacks of low levels of traceability, scalability, and data accuracy. Shahbazi et al. (2021) [41] suggested a blockchain- and machine-learning-based food traceability system (BMLFTS) that relied on a fuzzy logic approach that improved perishable food shelf-life management. The BC was used to reduce warehouse and shipment times and thereby improve reliability. Alfian et al. (2020) [42] proposed an IoT-based traceability system that utilized RFID and raspberry pi-based sensors. The RFID reader tracks and traces the merchandise while the raspberry pi is used during storage and travel to record temperature and humidity and forecast future temperatures. Sometimes, the food supply chain involves multiple stakeholders and distributors, which always leads to information asymmetry. To counteract, Mao et al. (2018) [5] designed a blockchain-based credit evaluation system to enhance food supply-chain monitoring and management efficiency through intelligent and innovative Long Short-Term Memory Network contracts (LSTM).

2.7. Digital Twins & Cyber-Physical Systems in FSC

The adoption of diverse technologies has aided in the advancement of food processing and logistics. To improve insights and optimize designs and processes, more sophisticated numerical tools and software platforms have emerged. The concept of the digital twin was successfully introduced as a valuable tool in the context of industrial digitization [43,44]. The digital twin is a virtual clone of a real-world process, connected to the environment via Big Data tools to analyze the functions of more physical models. This enables us to model and virtually visualize environments and processes risk-free, which is very apt for the present COVID-19 conditions [45]. The supply chain-based digital twins provide end-to-end visibility along with demand charts, levels of inventory, and asset management [46].

Furthermore, cyber-physical systems have evolved as intelligent mechanical entities that help in the smart production and packaging of products. Therefore, it can be easily linked with IoT, AI, and ML for better performance [47]. One good example of a digital twin application in FSC is portrayed by [48]. They created a digital fruit twin based on mechanistic modelling mimicking the thermal behavior of food products (fruit) across the cold chain, and quantified the enzymatically driven, temperature-dependent biochemical breakdown processes. This improves supply networks by documenting and predicting where temperature-dependent food-quality loss happens in each supply chain due to extended refrigeration times.

3. Methodology

The selection of keywords and the database were the first steps in this study. The authors used the Scopus database for this study because it enabled them to investigate a broad spectrum of publications. The primary keyword, food supply chain, was entered into a title search option followed by Internet-of-things, Big data, Digital twin, Artificial Intelligence, Machine learning, Cyber-Physical Systems, Blockchain, and Industry 4.0 title-abstract-keyword search option. The time-frame was limited from 2010 to 2021 (current). The authors selected only the articles that were published in English journals and excluded review papers. Conference papers were included because of their novelty, latest findings, and research proposals published in the conference proceedings.

The search code applied was as follows:

(food AND supply AND chain) AND TITLE-ABS-KEY (technological AND advancements) OR TITLE-ABS-KEY (internet AND of AND things) OR TITLE-ABS-KEY (big AND data) OR TITLE-ABS-KEY (digital AND twin) OR TITLE-ABS-KEY (artificial AND intelligence) OR TITLE-ABS-KEY (machine AND learning) OR TITLE-ABS-KEY (cyber AND physical AND systems) OR TITLE-ABS-KEY (block AND chain) OR TITLE-ABS-KEY (industry 4.0)) AND PUBYEAR > 2009 AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (LANGUAGE, "english")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p")) Results.

Initially, 156 documents were obtained. Then, the duplicates were removed, and authors thoroughly read the title and abstract of all the papers to scrutinize and bring down the number to 112 final datasets. A detailed methodology with a schematic is shown in Figure 1.

The dataset was snowballed to obtain results such as publication trends and distribution, source of publication and related technological concepts they primarily focused on, research work that was highly cited in this area along with the current number of citations, FSC properties, and percentage of research work plotted against the respective technological tool inclusion, department-wise categorization, and related research work, and barriers in technological adoption in FSC with future research trends. Insights of systematic analysis assisted in systematizing and structuring the dataset and understanding the current trends and challenges in FSC.

A bibliometric analysis on keyword coupling (food safety, quality, and sustainability) was also performed with the same dataset to interpret the relevance and concentration of research work. The authors wanted to understand different clusters of research work on this area. All indexed keyword coupling was run to retrieve the word cloud and gain an overall idea of the research area targeted over the past decade, and the country-wise link strength and citations were retrieved to understand the research work conducted according to the geographical locations. In addition, the relevance between the publication sources was checked to study how the researchers coauthored and cited other research publications in other journal sources. The main agenda of using both forms of analysis is to reap maximum insights on the topic of study, identify research gaps to answer for the research questions, and to propose future research directions.

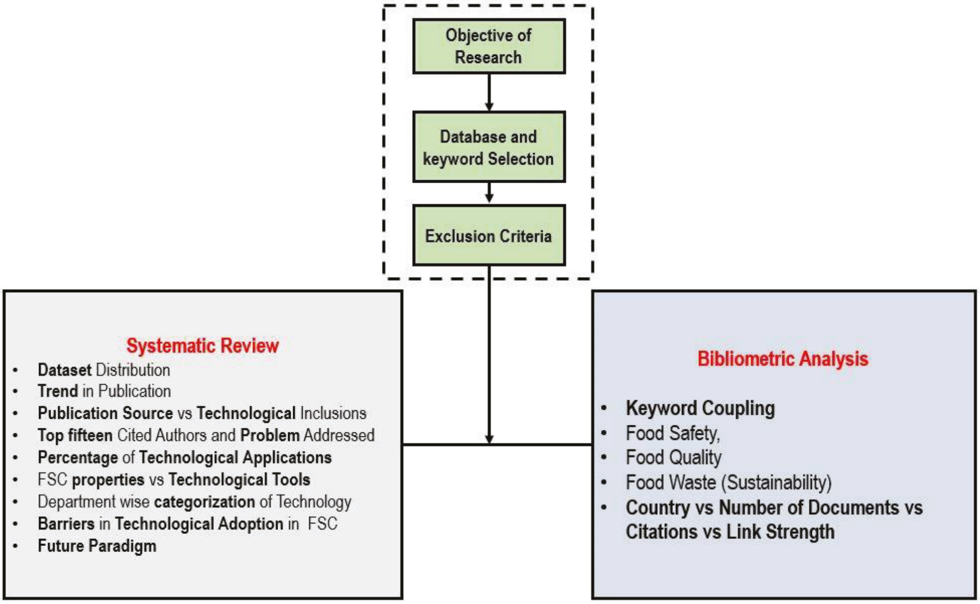


Figure 1. Methodology.

4. Results

The percentage of type of publications and datasets distributed was computed and projected in Figure 2. Conference papers accounted for 31% of the total publications. Figure 3 portrays the trend in publication. There is gradual rise, generating a good number of publications especially in the years 2017 and 2019.

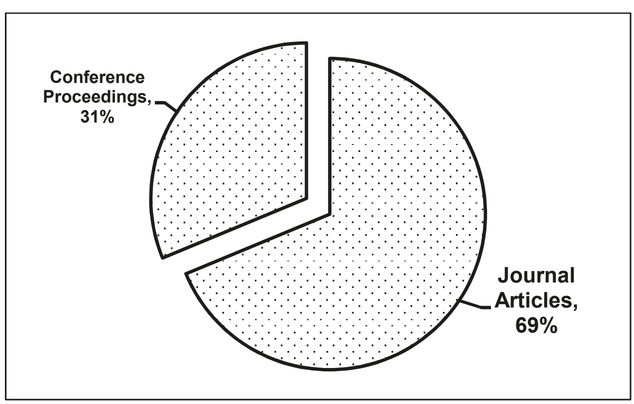


Figure 2. Dataset Distribution.

Table 1 displays the number of publications relating to technological advances in research work over the timeframe. The *International Journal of Production Research* and *Journal of Cleaner Production* have the most publications in the area of AI and blockchain applications in FSC. Furthermore, the top 15 most highly cited research works are tabulated in Table 2. The technological evolution has occurred gradually from applying RFID, IoT, blockchain, and AI.

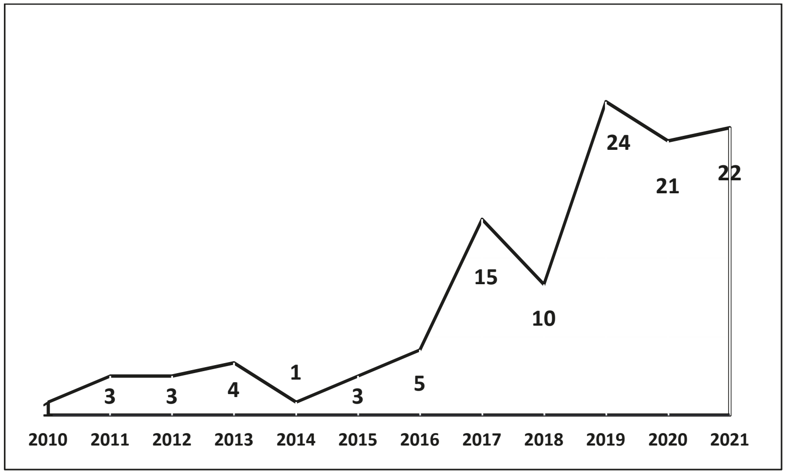


Figure 3. Trend in Publication.

Table 1. Source of Publications vs. Technology (Targeted Research Area).

Publication Source	No	Technology (Research Area)
International Journal of Production Research	5	Artificial Intelligence (Food Supply Chain Configurations), Mixed Integer Nonlinear Programming (Food Perishability), Blockchain (Food Traceability), Decision Support Systems (Arima, Arimax Machine Learning) Dynamic Network Sensors (Pricing Chilled Food Supply Chain).
Journal of Cleaner Production	4	Blockchain (Traceability, Tracking), Big data (Green Agrifood Supply-Chain Investment decisions), Decision-Making Trial Evaluation Lab (Reduce FSC risks)
Industrial Management and Data Systems, Production Planning and Control	3	Data-Driven Problem (FSC problems), Internet of Things (Perishable FSC), IoT (Tracking Prepacked Food Supply Chain), Blockchain (FSC Traceability)
2nd International Conference on Industry 4.0 and Smart Manufacturing, ISM 2020, *International Journal of Environmental, Research and Public Health, Computers in Industry, Food Control, International Journal of Supply Chain Management, Benchmarking, Foods, Sustainability* (Switzerland), *Technological Forecasting and Social Change*, Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management, IOEM 2020	2	Blockchain (FSC Traceability), Digital QR code (FSC safety), Fuzzy Logic (FSC Information), IoT (FSC Information Integration), Big Data (FSC sustainability, Integrity), Stochastic Modelling (Perishable FSC)

The abstract, title, and full text (only those available) were thoroughly reviewed by the authors to retrieve information on the percentage or volume of technological tools adopted in FSC-based research, which is shown in Figure 4. The inferences show that IoT and big data have been extensively applied; however, AI, ML, cyber-physical systems, digital twin, and blockchain technology still need more attention to discover further implications and benefits for FSC. Later, authors divided FSC based on food quality, safety, and waste and found out the relevant technological adoptions to meet the research objectives which is portrayed in Table 3. The findings reveal that IoT-assisted blockchain technology, RFID integrated with IoT, artificial intelligence, and machine learning were applied to improve food safety and quality.

Table 2. Author (top fifteen) vs. Problem addressed vs. Citations.

Author	Problem Addressed	Number of Citations
[49]	Integrated RFID (Radio-Frequency Identification) and blockchain for an agrifood supply-chain traceability system (production, processing, warehousing, and sales)	465
[50]	Built a food supply-chain traceability system for real-time food tracing based on HACCP (Hazard Analysis and Critical Control Points), blockchain and Internet of Things.	263
[51]	Presented AgriBlockIoT, a fully decentralized, blockchain-based traceability solution for Agrifood supply chain management.	175
[52]	Analyzed the concept of virtual food supply chains from an Internet of Things perspective and proposes an architecture to implement enabling information systems in a Fish Supply Chain.	147
[53]	Proposed a value-centric business–technology joint design framework for acceleration of data processing, self-learning shelf-life prediction and real-time supply-chain replanning.	139
[54]	Proposed big-data analytics-based approach that considers social media (Twitter) data for the identification of supply-chain management issues in food industries.	89
[55]	Proposed a food-safety prewarning system, adopting association rule mining and Internet of Things technology, to timely monitor all the detection data of the whole supply chain and automatically prewarn.	76
[24]	Proposed a blockchain-inspired Internet-of-Things architecture for creating a transparent food supply chain by integrating a radio frequency identification (RFID)-based sensor at the physical layer and blockchain at the cyber layer to build a tamperproof digital database to avoid cyberattacks.	67
[56]	Proposed a supply-chain quality sustainability decision support system (QSDSS), adopting association rule mining and Dempster's rule of combination techniques.	66
[5]	Provided a blockchain-based credit evaluation system to strengthen the effectiveness of supervision and management in the food supply chain.	61
[57]	Identified the various barriers that affect the adoption of IoT in the retail supply chain in the Indian context and also investigates the interdependences between the factors using a two-stage integrated ISM and DEMATEL methodology.	52
[29]	Investigated the potential benefits of the chilled-food chain management innovation through sensor data-driven pricing decisions to predict the remaining shelf life of perishable foods.	48
[58]	Proposed an effective and economical management platform to realize real-time tracking and tracing for prepackaged food supply-chain based on Internet of Things (IoT] technologies, and finally to ensure a benign and safe food consumption environment.	46
[59]	Discussed goals and strategies for the design and building of an IoT architecture aiding the planning, management and control of the Food Supply Chain (FSC) operations using a simulation gaming tool embedded with IoT paradigm for the FSC applications.	40
[60]	Proposed a blended, grey-based Decision-Making Trial and Evaluation Laboratory (DEMATEL) model to assess the relationships among the identified major risks in FSCs.	39

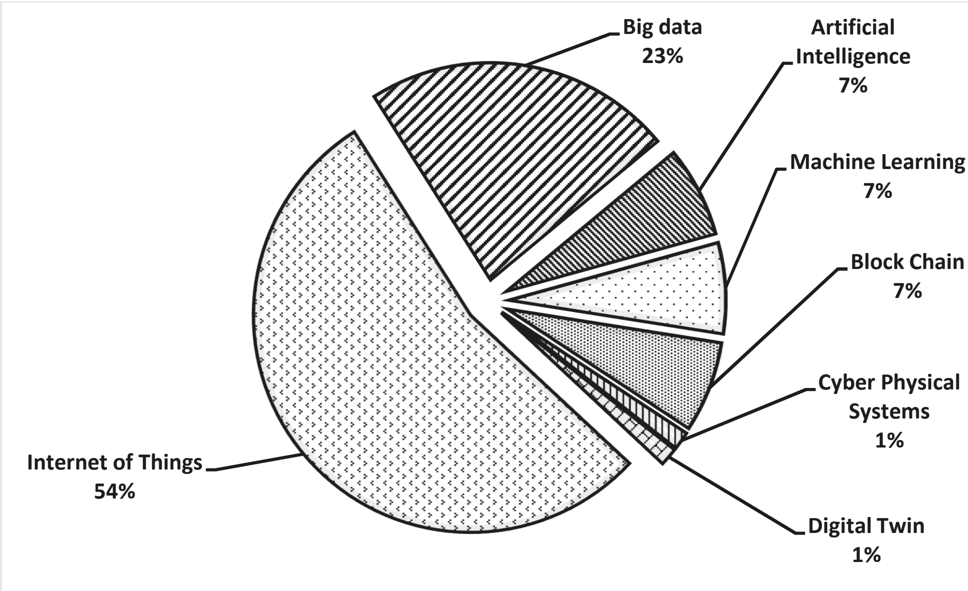


Figure 4. Percentage of Technological Tools.

Table 3. Properties of FSC vs. Proposed Technologies.

Reference	Food Quality	Food Safety	Food Waste	Proposed Technologies
[61]		✓		Cyber-physical network systems (monitor food contamination)
[22]		✓		IoT—blockchain-driven traceability technique for data transparency
[62]			✓	Smart sensing technology to enhance food quality and freshness
[20]	✓			Blockchain- and IoT-based traceability system for food waste
[25]		✓		Cost-of-food traceability using blockchain
[40]			✓	IoT-based inventory network tracing to minimize food waste
[63]		✓		To check for adulteration and foodborne diseases—Traceability using grey Dematel approach
[42]	✓			RFID-coupled, IoT-based food-quality forecasting
[48]			✓	Digital twin-based behavioral modelling
[64]		✓		IoT-based agrifood logistics system architecture
[49]		✓		RFID-integrated blockchain for food traceability
[65]			✓	Food supply-chain monitoring and planning using IoT

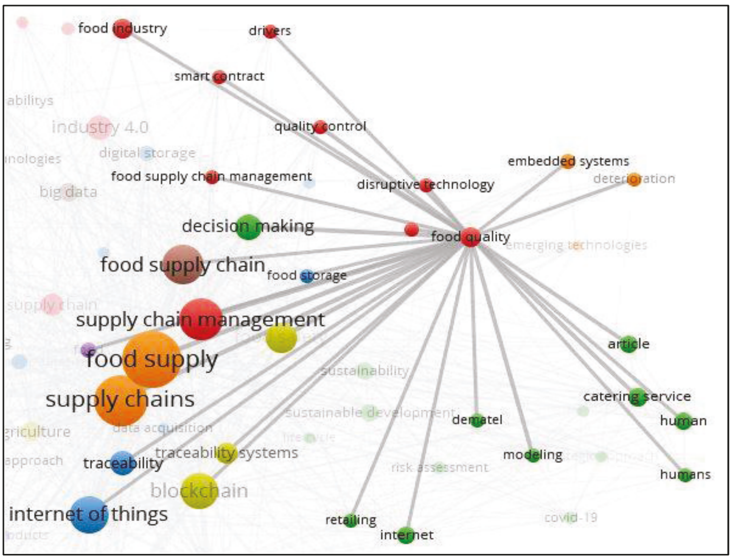
The FSC was classified into Production and Processing, Food Tracking and Traceability, Warehousing and Packaging, Logistics Branding, Marketing & Sales, and the corresponding technology applied. This classification was performed to obtain an in-depth idea of the technological tools and advancements at different stages of the food chain, starting from raw materials and ending with finished goods. This information is tabulated in Table 4. The results show that more research has been conducted on food traceability and tracking in recent years.

Table 4. Department-wise Categorization of Technological Tool Adoption.

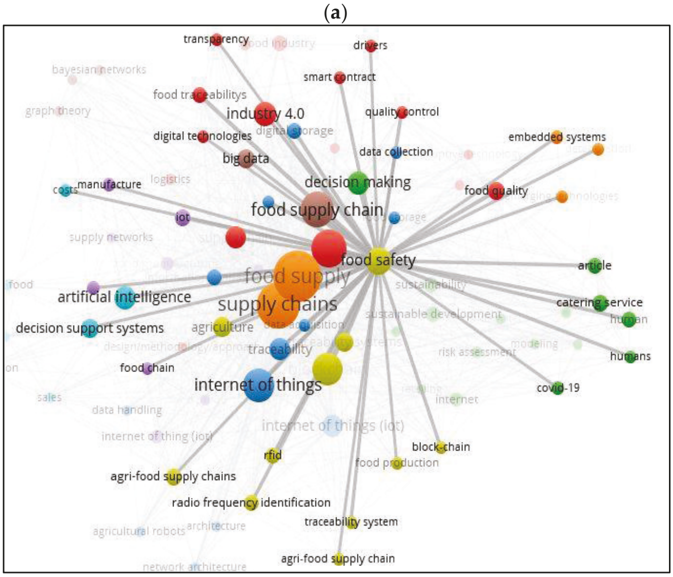
Reference	Food Production and Processing	Food Tracking and Traceability	Warehousing and Packaging	Logistics	Branding, Marketing & Sales	Technological Tool Applied & Purpose	Publication Source
[20]		✓				Blockchain-based food traceability to ensure safety	*Foods*
[66]	✓					Blockchain integrated with QR code and built FoodSQRBlock in food production (scalability and feasibility)	*Sustainability*
[67]			✓	✓		Enhanced naive Bayes approach and IoT integration in warehousing and transportation	*International Journal of Scientific and Technology Research*
[3]	✓					Smart Farming Technology Framework	*Land Use Policy*
[68]	✓					Producer-to-consumer food production and quality-based blockchain ledger	*Quality—Access to success*
[41]		✓				Blockchain machine-learning-based food-traceability system (BMLFTS) to improve food readability, scalability and improve anticounterfeiting	*Electronics*
[69]			✓	✓		IoT-enabled supply-chain parameters and modelling	*Industrial Management and Data Systems*
[37]	✓					AI adoption to address operational efficiency in food production at SMEs	*HSE Economic Journal*
[70]					✓	Decision support systems (Arima, Arimax) for food sales forecasting	*International Journal of Production Research*
[22]		✓				IoT- and blockchain-driven food traceability	*International Journal of Information Technology*
[4]		✓				Blockchain-based diary product supply-chain traceability	*International Journal of Production Research*
[38]				✓		AI-based energy savings in food logistics	*IEEE Industrial Applications of Artificial Intelligence (2020)*
[71]		✓				Bayes classifiers algorithm integrated IoT for food supply-chain traceability	*International Journal of Engineering and Advanced Technology*
[63]		✓				Grey Dematal approach for food traceability	*Information Processing in Agriculture*
[72]				✓		Internet of perishable logistics for food supply-chain networks	*IEEE Access*
[73]					✓	Determinants of food safety level using smart technology	*International Journal of Environmental Research and Public Health*
[74]					✓	Electronic Product Code (EPC)-based Internet of Things for food sales monitoring	*International Journal of RF Technologies*

5. Bibliometric Analysis of Food Safety, Quality, and Sustainability Using Keyword Coupling

A bibliometric keyword coupling was conducted using the Vosviewer software on the dataset with 978 keywords. The number of keyword repetitions was set at three, in which 83 keywords met the criteria. The keyword nodal burst was separately captured from the bigger image and projected as Figure 5a–c to visualize food quality, safety and waste (sustainability). The authors selected the sustainability keyword-based nodal image in the keyword coupling related to food waste, since the waste node was much smaller and meagerly relevant compared with the other bibliometric, full-factorial coupling clusters.

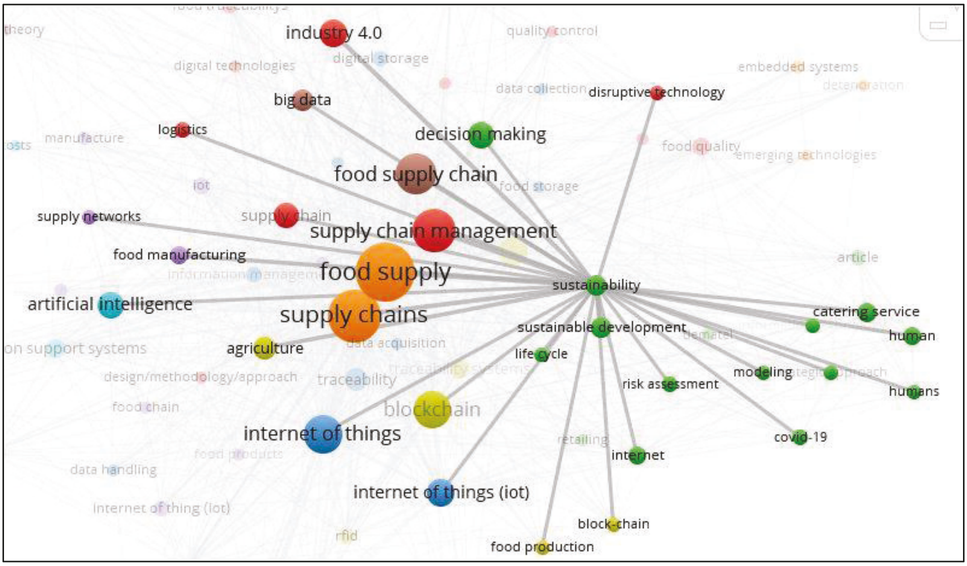


(**a**)



(**b**)

Figure 5. *Cont.*



(**c**)

Figure 5. (**a**) Food Quality, (**b**) Food Safety, (**c**) Food Waste (sustainability).

The keyword bibliometric coupling results show the relevance of the research area (keyword) and the intensity of work done based on the distance between them and the size of the node, respectively [43,75]. Inferences can be retrieved by identifying the gaps and future research work. The results from 5a reveal that smart contracts have been deployed in the food industry to maintain food quality. IoT, embedded systems, and Dematel Fuzzy logic algorithms are the primary tools related to food quality maintenance. Whereas IoT, AI, radio frequency identification device (RFID), embedded systems, and big data have all contributed towards maintaining food safety, as shown in Figure 5b. However, IoT and big data are in different clusters with less relevance. This indicates that more research is needed to understand the challenges and drivers of those technological adoptions in FSC from food safety. The same tools are also assisting in sustainability but are seen even farther apart in the nodal burst. The interpretation of the results from Figure 5c keyword burst shows that food waste or sustainable norms of food production and logistics are still in their infancy.

Indexed Keyword Coupling

Another set of keyword couplings on the indexed keyword set was conducted to visualize the overall keyword cloud. The minimum number of keyword occurrences were three, and 59 met the threshold out of 741 keywords. The indexed keyword coupling based on text mining has been shown in Figure 6. Five clusters have been identified from the word could. Artificial Intelligence, decision support systems, and big data (data mining) are grouped along with the agricultural systems and food traceability. A separate cluster has been generated for food storage and traceability related to food safety. RFID, IoT, blockchain, and agricultural robots are grouped in a separate cluster. Sustainability and strategic decision making for risk assessment seem to be very close and relevant.

The dataset was further reviewed to generate country-wise relevance, number of documents, and total citations per country. A maximum number of research and citations in FSC and technological adoption has been seen in the United Kingdom, followed by India, China, Turkey, and United States. The minimum number of documents and citations per country was fixed as two. A total of 26 countries out of 33 met the criteria as tabulated in Table 5. This inference is crucial to finding out from which countries researchers and institutions contribute more towards FSC and push other researchers to discover their objectives.

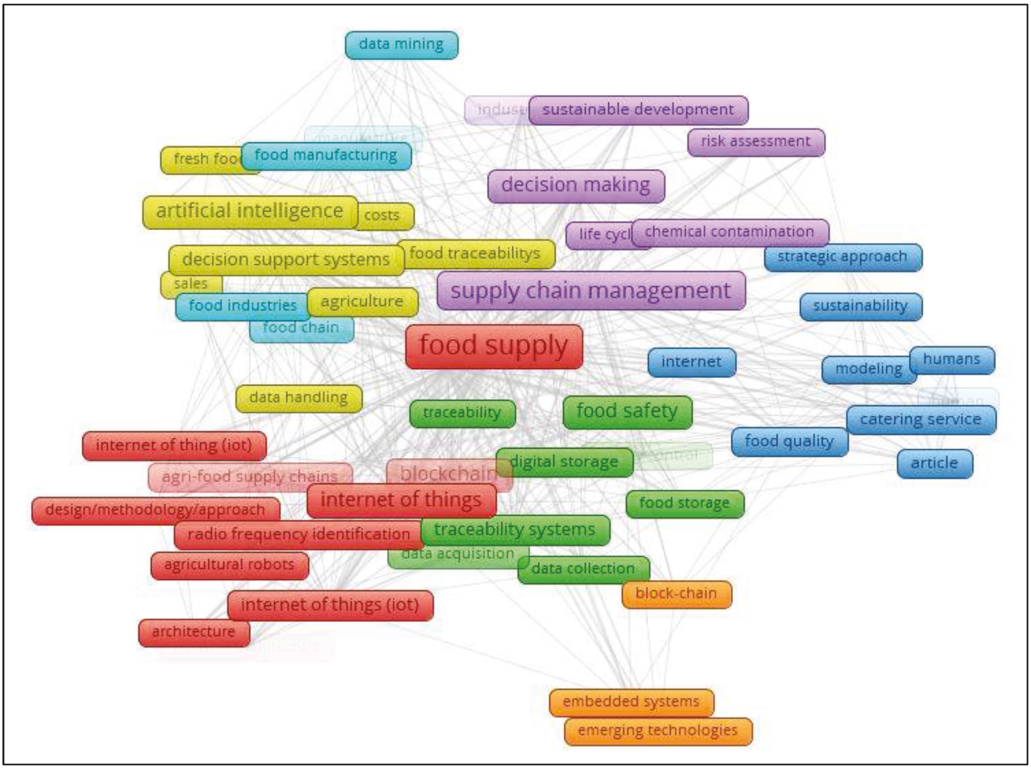


Figure 6. Indexed keyword coupling.

Table 5. Research Link Strength and Citations between Countries.

Country	Documents	Total Citations	Link Strength
United Kingdom	22	276	1943
India	20	131	1686
China	25	481	855
Turkey	3	16	841
United States	9	206	692
Canada	6	53	576
Italy	11	295	340
Netherlands	6	252	337
Indonesia	2	4	273
France	5	73	248

Later, the bibliometric coupling on sources was conducted with one article having a minimum of 10 citations. Out of 90 sources, 29 were the most relevant, which is clearly shown in Figure 7. The larger the nodes, the greater the research volume, and the closer the nodes more relevant the research work. *International Journal of Production Research*, *Journal of Cleaner Production*, *Sustainability*, *Industrial Management and Data Systems*, *Information*

Systems Frontiers, and *Food Control* are the journals that have been extensively published in these areas.

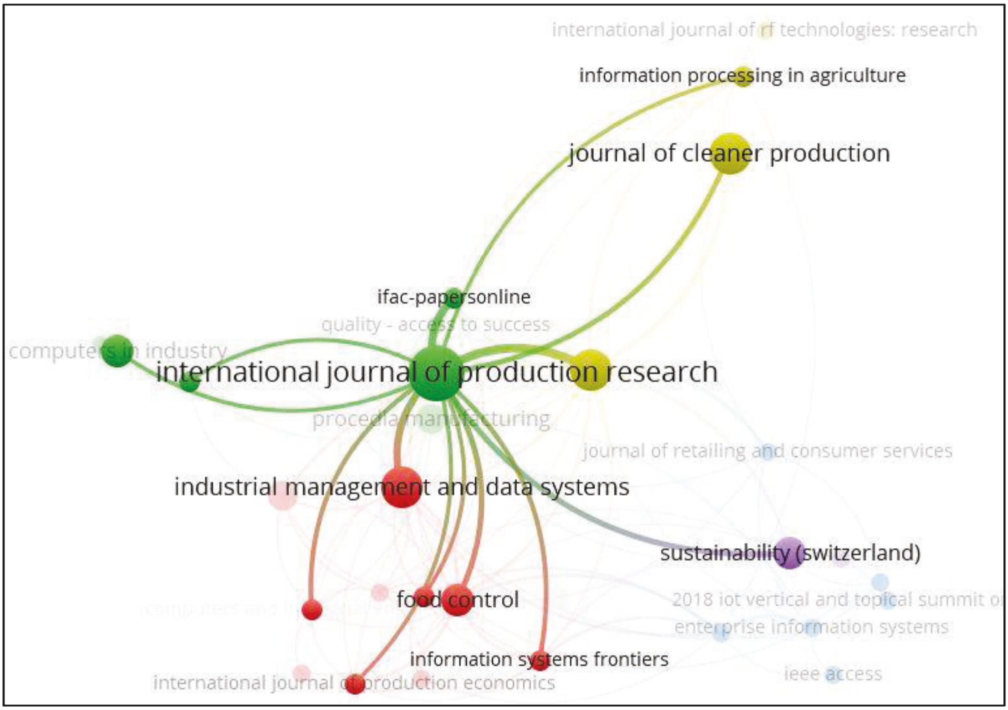


Figure 7. Bibliometric coupling of Journal Sources.

6. Discussion

Global warming, population growth, industrialization, and the need for sophisticated food systems are all being addressed by innovation. Applying technologies in monitoring ecological effects, smart farming, and value addition for future smart value chains has a tremendous and intriguing perspective. For predicting and forecasting crop cultivation, reaping time, and grade, technologies such as AI are employed to find in-time conveyance and optimized market outreach. This systematic review and bibliometric analysis yielded a set of research implications, which the author discusses in depth in the sections below.

6.1. Effect of Current Pandemic on FSC

The COVID-19 outbreak gave birth to a new phase in the food sector and supply chain. The repercussions on humankind, the economy, and food safety are still being worked out. Food scientists and experts face numerous issues, including securing food safety, identifying SARS-CoV-2 locations where food is produced, processed, and distributed, and effectively sanitizing surfaces and working areas. More precautions are required as we progress to the final stages of the supply chain, as more people are involved in the process. Food monitoring and surveillance would become increasingly reliant on the development of effective bioanalytical technologies [76].

The pandemic is responsible for rapid shifts in the foodservice to retail food patterns requiring flexible FSC. Potential long-term changes in the supply chain include greater food supply-chain automation and digitization. In addition, technological investments in online delivery infrastructure have changed retail food landscapes. Nonetheless, the danger of labor scarcity due to worker sickness, self-isolation, or movement constraints has critical consequences and makes FSC more vulnerable. Significantly, in the meat processing and general food packaging industries, the demand has increased substantially [77].

The working atmosphere experiences a complete transformation where most of the work is from home, depending on digital communication and contactless electronic communications. Therefore, the technological inclusions in the food system that have been incorporated, especially in areas such as quality control, verification, and certification, have improved FSC. However, the physical inspection of food items during the packaging and logistics procedures are still facing challenges due to disruptions in the supply-chain footprints [13,78].

Policy guidelines and operations are being amended continuously. There is a greater need to tap and leverage the full capability of IR 4.0 technological tools and protocols to overcome the challenges due to pandemic disruption. Truck routes can be optimized, warehouse locations can be divided and scattered, we could rely on locally grown crops, implement agile and lean methods in agriculture, and most importantly the supply chain footprints should be planned to create supply-chain viability.

6.2. Technology and Food Sustainability

The current scenario necessitates the convergence of appropriate supply-chain systems with industry 4.0 to maintain sustainability. An intelligent food-production system can effectively address challenges in food safety, security, control, and perishability [17]. One of the biggest reasons for the world's existing sustainability challenges might be attributed to the lack of potential to incorporate technological advancements effectively [79].

Given the perishability of food and the importance of food safety in agricultural goods, a better technology-driven strategy is required at every stage of the food supply chain during processing and manufacturing to avoid waste and assure high-quality end products [17,80]. To bolster these facts, Belaud et al. (2019), [81] developed a big-data integrated food supply-chain design for the bioconversion of lignocellulosic biomass, creating environmental sustainability in the agricultural waste valorization domain. These technologies directly and favorably impact traceability, compliance, and coordination between FSC actors and their adoption-intention decision processes that generate scalable, interoperable, and cost-effective architecture for supply-chain integration and sustainability [82].

6.3. Scope for Circularity in Food Supply Chain and Waste Management

Many research projects are focused on reducing food waste. Product deterioration and decomposition were identified as three main sources of food waste during logistics [83–85]. Food organizations are trying to adopt circular economy strategies to improve supply-chain ecological stability. However, from the perspective of underdeveloped nations, the adoption of circular economy and sustainability elements is more complicated than in rich countries. An excellent sustainable strategy shall rewrite poor government policies, lack of technology and practices, and lack of awareness and education. These are among the main obstacles to a successful circular economy-led sustainable supply-chain integration [86].

Green and sustainable supply-chain management methods have emerged in recent decades to incorporate environmental concerns within organizations by avoiding unexpected negative environmental repercussions due to consumption. Parallel to this, the circular economy concept has gained traction in the literature and in practice in industrial ecology. The circular economy pushes the bounds of environmental sustainability by emphasizing the idea of designing the products so that there are viable linkages between ecological systems and product consumption [87].

6.4. Technological Adoption in FSC and Challenges

Effective management of food safety and security, demand and supply shortages, quality of products, and traceability, can bring economic and social progress in the food sector. Technological tools provide viable and protracted platforms to reduce human intervention and error [88]. Reconceptualizing supply-chain design and operations with the help of digital technologies helps in overcoming the barriers in FSC [89]. However, very little research has been conducted on the factors that affect these technologies' adoption to attain supply chain 4.0. More research into the perceived drivers and hurdles to implementing supply chain 4.0 in the context of FSC is required. The significant challenges and barriers are supply–demand imbalance, rapidly changing customer expectations, legal ramifications, cost optimization, and lack of organizational collaboration [90].

The introduction of blockchain technology resolves many challenges related to food integrity, traceability, and audit [80]. Casino et al. (2021) [4] stated that upstream and downstream supply-chain players are pushed to store and manage traceability-related data to provide proof of regulatory compliance to government authorities. Tian et al. (2017) [50] developed a food supply-chain traceability system for real-time food tracing based on HACCP (Hazard Analysis and Critical Control Points), backed by blockchain and the Internet of Things, which provided an open, transparent, neutral, reliable, and secure information platform for all supply-chain members in FSC. Chen et al. (2017) [91] introduced a unique, intelligent, predictive food traceability with a cyber-physical system coupled with simulation modelling by combining intuitionistic-based fuzzy case-based reasoning with enterprise architecture and value stream mapping. The CPS-based food traceability system was utilized to identify traceable objects that are reactive to a broader range of intelligent food traceability using a novel approach for traceability performance-prediction behavior.

IoT can give concrete and commercial benefits to FSC, hence improving the efficiency and productivity of operational procedures. However, it is increasingly difficult for retailers to adapt their marketing strategies to shifting consumer behavior as the food retailing industry becomes more complicated and flexible. Internet of Things (IoT) is intended to assist businesses in checking the quality of food products, planning waste management for things beyond their shelf life, managing shop temperatures and other equipment that reduces energy use. As a result, the adoption of IoT is currently in infancy, despite its enormous potential [57]. Cyber-physical systems (CPS) have now been introduced to take care of food traceability from a future internet perspective to display intelligent behavior such as smart predictive business practices in the FSC. Nonetheless, the CPS-based food traceability system faces several new issues, including communication efficiency, heavy capital investment, and system architecture requirements [91].

6.5. Role of Technology in Food Relationship Strategies

Horizontal collaboration and relationship policies between FSC players are the need of the hour, where there are very minimal supply chain footprints and routes, especially during this COVID-19 pandemic. Therefore, proper collaboration and cooperation strategies in food supply chains can improve resource usage and market governance. Furthermore, they can assist in enhancing the FSC resilience and all three different dimensions of sustainability [92,93]. Effective relationship strategies through horizontal and vertical collaborations improve cost and quality in FSC [94,95].

Designing processes to jointly reap the benefits via developing goals and also investing in capabilities and assets are very essential. Technological implementation will ease the planning and goal-sharing setup in FSC. State-conflicting goals should be avoided by framing better relationship strategies. Blockchain-based smart contracts in the food supply chain and IoT-assisted big-data cloud technology can help overcome this challenge by setting up secure contracts between stakeholders and increasing FSC integrity [96].

The blockchain smart contract would have an RFID identifier preinstalled that would retrieve information on the area, state, nation, time related to product packaging, storing, transportation, and product quality. An ID tag is a setup in the RFID label that would be integrated with the blockchain to store permanently immutable information for secured time-stamped transactions. Collaboration and establishing business contracts among the food supply-chain players to incorporate food relationship strategies is eased by this protocol [97].

Furthermore, technological platforms can be shared between competitors to enable an effective downstream horizontal collaboration through mutual trust and benefit sharing [98].

6.6. Food Supply Transformations through Technology

Achieving food-system sustainability is a global concern, especially knowing how in-parallel food supply transformation could be accomplished. The practically feasible role of technology and human engagement with agricultural systems are pondered to streamline this food supply-chain transformation. Food sustainability, integrity, traceability, safety, waste management, and pandemic disruptions are major elements in the FSC to be considered for transformation and more resilience [12,99,100].

Technology adoption in FSC creates transformation both in the quality and safety of food products. Moreover, technology has been adopted to improve resource efficiency and productivity in food systems. This has reduced agricultural raw material inputs to reduce environmental externalities. Many farms across the world are applying big data and data analytics in equipment maintenance, field mapping, and other operational activities to optimize irrigation to improve the productivity of agricultural practices. Additionally, digital-twin technology-based geographical information systems (GIS) are adopted to perform precision agriculture that allows the utilization of sensors to optimize the use of pesticides, fertilizers, and water. Moreover, other decision support systems help farmers to maximize production efficiency while minimizing production costs and the environmental footprint of their operations. These aspects serve as a building block for the transformation of food systems [101].

7. Future Research on Technological Inclusions for Food Supply-Chain Transformation and Innovation

After a systematic literature review and bibliometric analysis, authors have accumulated insights on the future research scope and direction. More research should be focused on innovating agricultural farming, production, and processing with the help of smart supply chains and digital technologies. There are significant research opportunities if artificial intelligence and machine learning are applied to control food transport optimization issues, demand-forecasting, prescriptive shipping technologies for perishable food products, and organizing safety and quality in the food chain. The percentage of customer satisfaction should be kept as a key performance index during the integration of technological tools and FSC. Blockchain-based smart contracts can be built to complete state-of-the-art functional and purpose-driven supply-chain and financial transactions. Moreover, the food supply chain needs to be strengthened more from all three facets (food quality, safety and sustainability) in order to fight the COVID-19 pandemic disruptions. Additionally, IoT-assisted big data can build horizontal collaborations that improve food relationship strategies.

Government policies, approvals, and audits can be digitalized using the blockchain and IoT to increase FSC resilience. Blockchain platforms can also create traceability certificates capturing all the supply chain footprints. Cyber-physical systems can directly help in food processing and packaging in this and next decade, where fewer human interactions are desired due to the pandemic. The quality of the FSC from a micrologistics perspective can be improved using cyber-physical systems and smart robotics in the food processing and packaging area. Blockchain and big-data-driven technology can assist farmers in practicing responsible procurement to maintain sustainability standards, both environmentally and economically. A complete food supply transformation-based operational paradigm is shown in Figure 8. After a detailed review of the dataset, the authors propose related technological interventions that are required at different stages of the FSC. It displays barriers and challenges at the different echelons of FSC and the technology tools that can be applied to overcome them and create scalability for more supply chain 4.0 drivers in FSC.

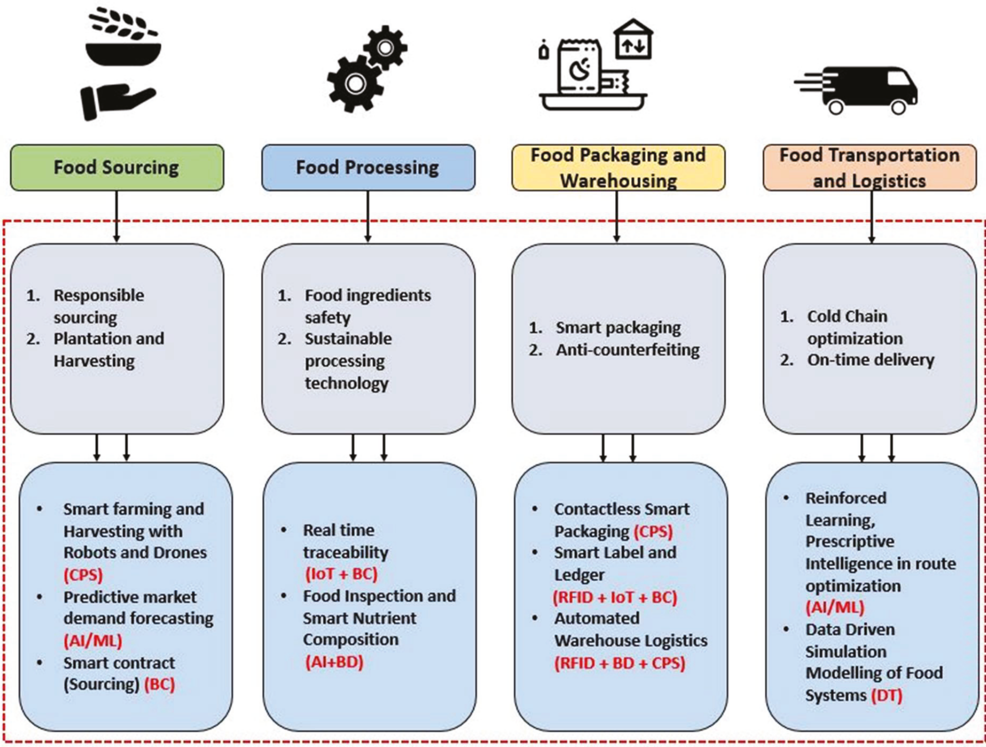


Figure 8. Food Supply Chain 4.0 Operational Paradigm.

The costs associated with FSC such as logistics, freight, energy, fuel, workforce, and capital investment in technology should be kept to a minimum to suppress the bullwhip effect in the chain. IoT-assisted big data can help in this aspect by creating cost patterns in the data warehouse and showing the predictive and prescriptive solutions for better decision making using machine-learning algorithms. In addition, a high level of quality and safety is needed for final food products at all times, both globally and locally. Enhancing the visibility and interaction in the FSC, a business can witness significant gains.

8. Conclusions

This study aimed to systematize the previous literature on FSC and the application of IR. 4.0 tools, and review how the past research has been focused on counteracting the disruptions in FSC. More problems need to be addressed regarding how to effectively integrate one or more tools to reap maximum benefits. Very few studies have applied blockchain (integrity, security), artificial intelligence and machine learning (error-free prescriptive platform), digital twin, or cyber-physical systems within the scope of the study. Additionally, there is a need to build more digital support systems for FSC to improve decision making, especially within pandemic conditions.

More studies must be focused on avoiding food wastage. However, technical failures in the supply chain eventually result in food waste. The cost of monitoring suppliers makes it difficult for retailers to embrace new and innovative suppliers. More modern automation in food systems has piqued the interest of food manufacturers regarding long-term investment. Unquestionably, the impending food catastrophe cannot be cleared overnight. The apparent benefit of digitization is that it helps to reduce waste that could otherwise be avoided. When one out of every three freight journeys is for food, generating better real-time data to enhance routes and distribution planning is critical. Furthermore, by utilizing digital and automation technologies, food loss may be avoided and costs can be drastically reduced. When real-time data is used with a variety of sustainable indicators, businesses may drastically cut yearly energy utilization.

Future research should be aimed at improving the level of digitalization, marching towards strong traceability systems that can control food advocacy, source, and safety during this pandemic, where counterfeiting and adulteration can more common than usual. Moreover, digitalization offers a complete audit trail of trustworthy information that enables the supplier to enter the supply chain with the capacity to validate the quality of the production and the procedures at all stages, from farm to retailer. More research should be focused on traditional food procurement methods that have spawned both consumer expectations and misconceptions. Consumers should be more informed and educated about food quality and its health consequences. The use of technological instruments reduces waste in FSC, strengthens its resilience, and increases viability. The changing end-to-end business model relies mainly on revolutionary innovation in the food sector. Food safety and advocacy will improve as a result of embracing digitalization, allowing the market to democratize accessibility and experiment. All of this is possible due to the industry's automation, increased efficiency, improved consumer knowledge, and support for important food production and consumption changes.

Furthermore, achieving transformation in the food system would need a significant shift in attitudes, as well as the roles and duties of public sector actors versus corporations in determining food demand. This can be achieved by properly planning horizontal collaboration protocols in FSC. Economic development, human health, and planetary health are all dependent on food systems, and getting all three right is critical. They are intertwined and have a significant impact on one another. Every nation must conceive prospective future possibilities in which everyone consumes adequately, based on food systems that are ecologically, economically, and socially viable. Local and national perspectives on how such food systems would appear in their higher prevalence should guide policy goals intended to achieve long-term transformation.

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