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Understanding Firm Networks in Global Agricultural Value Chains

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Abstract

This paper explores the evolution and resilience of global value chains (GVCs) in the agrifood sector, which intensified since the 1994 Uruguay Round Agreement. Using unique data from the FactSet database, along with Fortune 500 lists, the comprehensive analysis of approximately 17,500 agribusiness companies worldwide examines more than 150,000 supplier and customer connections from 2014 to 2022. The findings reveal that large corporations, acting as central nodes, have increased their network centrality in global value chains, particularly through geographic diversification and a concentrated supply strategy. The study also indicates that there is a correlation between the complexity and depth of firm-to-firm linkages and increased resilience, suggesting that firms with greater connectivity are less likely to exit the industry. The analysis not only contributes new insights into the structure and dynamics of agribusiness networks, but also highlights the role of firm linkages in navigating recent disruptive global events, such as the United States-China Trade War, the COVID-19 pandemic, extreme weather episodes, and geopolitical tensions.

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1 Introduction

Since the Uruguay Round Agreement in 1994, global value chains (GVCs) in the agri-food sector have expanded significantly. Driven by regulatory changes, technological advancements, increased foreign direct investment (FDI), and shifting consumption patterns, these chains involve multiple firms across international locations, each specializing in specific tasks (Gereffi et al., 2005). Major corporations often orchestrate these networks, leveraging global differences in production costs and technological expertise. This model has thrived under policies aimed at reducing trade and investment frictions, illustrating the profound impact of globalization on production and trade, with about half of global trade nowadays consisting of products traversing multiple borders from start to finish (WorldBank, 2020; World Trade Organization, 2023).

However, anecdotal evidence suggests that recent events, including the US-China Trade War, the COVID-19 pandemic, the Suez Canal blockage, the invasion of Ukraine, and severe weather events pose potential major disruptions (Antràs, 2020; Garicano et al., 2022; Alfaro and Chor, 2023). These challenges have already started reshaping GVCs, including in agri-food, altering the significance of different players within the industry. For instance, during the COVID-19 crisis, many intermediaries in the fresh produce value chains exited the market, while large growers, manufacturers, and supermarket chains gained prominence. Firms that had previously diversified geographically and invested in creating backward and forward linkages with other critical industries (e.g. by creating e-commerce sales channels or investing in logistics adjustments and technological solutions) demonstrated greater resilience and adaptability.

These observations suggest the need for a detailed analysis of value chains, the role of large corporations within them, and most importantly, an exploration into how different types of firm-to-firm linkages may either expose some firms to fatal shocks or enable others to diversify and enhance their resilience. To investigate the aforementioned questions, we utilize the FactSet database along with the list of agri-food-related US Fortune

500 firms.

The FactSet database offers unique advantages as it provides information on firms' fundamentals matched with detailed information on firms' suppliers and customers, as well as ownership ties. This information is crucial for assessing a company's dependencies and market position. Given its global coverage, the dataset allows for a comprehensive understanding of the complexity and geographic dispersion between companies. Finally, since the dataset tracks variables over time in a precise manner, it enables the analysis of trends and changes within these relationships over the years.[1]

To maximize the utility of the data while minimizing the potential for error, we undertake three primary analyses. Initially, we perform a descriptive exercise using network analysis metrics to examine the role of US Fortune 500 firms, specifically the 48 influential American lead firms in GVCs identified from this list, within the agri-food value chains. This focus is chosen based on the ability of these firms to exemplify significant economic influence within the national agri-food sector.[2] Our findings reveal that the Fortune 500 lead firms are notably more interconnected and increasingly central to the agro-food GVCs. However, since 2018, they seem to be concentrating their activities within their corporate boundaries, in contrast to non-US-based firms.

This observation leads us to conduct a broader and systematic firm-to-firm connectivity analysis. We expand our inquiry to include all firms listed in the FactSet database that operate in agri-food-related sectors. Our findings indicate that the most connected firms are also those that have significantly increased their number of customers and suppliers over time. Furthermore, a relatively small group of highly interconnected firms consistently occupies central positions within the network. Despite their central roles, these firms typically do not diversify their core relationships within narrowly defined indus-

[1] FactSet's coverage is particularly strong in the United States, where the firms in our sample account for around 80% of aggregate industry output.

[2] The substantial coverage of both Fortune 500 and non-Fortune 500 US agribusinesses in our sample justifies the initial US focus to effectively detect and compare the relevance of these companies with non-Fortune 500 firms.

tries. Instead, they maintain a stable number of relationships within their industries while expanding their reach across different industries and diversifying geographically. Generally, firms with at least one international link tend to maintain more connections, with the average number of links for this subset increasing between 2014 and 2022. This trend suggests a pattern of "concentration of supply and diversification of demand", wherein firms rely on established partners for specific tasks while innovating and diversifying by extending their networks to new partners mostly from other industries, and by broadening their geographic footprint.

The aforementioned stylized facts raise a critical question about which firms are poised to succeed in this evolving landscape. Hence, we conduct an empirical investigation of firm success. To leverage the data effectively, we focus on the likelihood of firms exiting the agri-food industry, differentiating their linkages by backward and forward integration, geographic reach, and nature. Our analysis shows that firms are generally less likely to exit the industry when they have a greater number of linkages, with supplier connections being particularly influential in this correlation.

This paper advances the growing body of literature on agri-food Global Value Chains (GVCs) by conducting a detailed analysis of firm-to-firm networks at the firm level, a perspective often neglected due to the lack of detailed data (Scoppola et al., 2022). While existing research has largely focused on the macro dynamics, covering aspects such as trade policy, structural transformations, and productivity within agri-food GVCs (Balié et al., 2019; Lim, 2021; Montalbano et al., 2020; Lim and Kim, 2022; Dalheimer et al., 2023), it has generally been constrained to country or industry-level analyses.[3] These studies, typically reliant on multi-regional input-output data, provide valuable insights yet fail to adequately capture the intricate web of interconnections that characterize firm-level operations across borders.

[3]Recent research on the agricultural GVC includes the following studies: trade policy and GVC participation are discussed in Balié et al. (2019), structural transformation in Lim (2021), agricultural productivity in Montalbano et al. (2020), employment in Lim and Kim (2022), and food prices in Dalheimer et al. (2023).

This research contribution seeks to fill that gap, offering new insights into the complex relationships that define global agri-food networks. By utilizing new, large-scale data, our approach meets the critical need for firm-level analysis, highlighted by Punthakey (2020); Amendolagine et al. (2017); Barrett et al. (2022) and contributes to understanding how individual firms influence and are influenced by the GVC setting, thereby filling an important gap in the literature on global agricultural trade and economic development.

The rest of the paper is organized as follows: Section 2 provides the motivation. In section 3, the data and methodology are discussed. Results are presented in Section 4, followed by a discussion on policy implications in Section 5. Section 6 concludes the paper.

2 Motivation

In an era marked by increasing global shocks –from the US-China Trade War and the COVID-19 pandemic to the Suez Canal crisis, the Russian Federation-Ukraine conflict, and escalating extreme weather events – the need to understand how these disruptions reshape global value chains (GVCs) has become essential. After decades of trade and investment liberalization, traditional business models have become deeply interdependent through these GVCs, a setup explored extensively in recent literature (WorldBank, 2020; Baldwin and Freeman, 2020; Seetharaman, 2020). The recent intensification of global shocks is upending these established models of production, necessitating unprecedented levels of agility and resilience from industries worldwide. In this context, the attributes of predictability and timeliness, long valued in GVC operations, are increasingly challenged.

The agri-food sector, particularly affected by these vulnerabilities, has seen significant risk management challenges emerge, adversely impacting its GVCs (Kerr, 2020; Arita et al., 2022; Ferguson and Ubilava, 2022; Engemann and Jafari, 2022). However, certain segments within this sector, notably the fruit and vegetables sector, have demonstrated

remarkable resilience. This section delves into four key adaptation strategies that have enabled the sector to leverage disruptive conditions for sustained operational success. We explore how these strategic adaptations are potentially reshaping economic dynamics and GVC structures within the sector, offering insights that could inform future resilience mechanisms for the broader agri-food industry. These adaptive strategies include:

Food Service to Retail As consumer habits shifted markedly from dining out to home cooking and healthier diets, demand for fresh produce surged (Beckman and Countryman, 2021).[4] The fruit and vegetables sector swiftly redirected its supply chains from food services to retail markets to accommodate rising demands in the US, Europe, and Asia. The closure of food services amplified the role of supermarkets and e-commerce, pivotal channels during the COVID-19 lock-downs, leading to sustained high retail volumes during the pandemic (Litton and Beavers, 2021).[5]

More Resilient Production and Supply Models Another critical adaptation was the diversification of the supply chain, mitigating risk and enhancing resilience. For example, Stevens and Teal (2024) shows that horizontal diversification has bolstered US firms' resilience, particularly among small and medium-sized businesses. The pandemic further necessitated rapid logistical adjustments as traditional supply routes were disrupted by global lockdowns and trade restrictions (Singh et al., 2021). In response, suppliers expanded regional trade and diversified their import sources, effectively reducing their vulnerability to single points of failure. This strategic shift to more resilient supply models is elaborated further by Ando and Hayakawa (2022); Pahl et al. (2022); Lebastard and Serafini (2023), who all highlight how diversification strategies have enabled businesses

[4]For additional anecdotal evidence, refer to Brandwatch (2020); Supermarket News (2020); FoodNavigator (2020).

[5]Sales from leading stores grew in the two months after the beginning of the lock-downs in all major markets. Supermarket sales for food were up 19% in the US, and 17% in the UK by mid-May 2020, according to media sources. Walmart and Target saw a total sales increase of 11%, Tesco 8.7%, and Costco 7.3% over the same period of time. This is notable given pre-crisis growth rates of around -3% to -5%.

to navigate and adapt to the challenges posed by the pandemic.

E-commerce and Other Strategic Backward and Forward Linkages The COVID-19 crisis accelerated the trend toward e-commerce and digital solutions, with the largest firms investing significantly in automation and digital technologies to streamline operations and reach consumers directly. For instance, research using extensive e-commerce data from China (Guo et al., 2021, 2022, 2023) finds that the COVID-19 pandemic has led to substantial growth in online sales of agricultural products, particularly fresh and perishable produce, which customers are more likely to repurchase. Additionally, firms have invested in genetic development and other R&D to not only survive but thrive in an increasingly uncertain global landscape.

Concentration of Activity within Major Agribusinesses Strategic investments have led to changes in the structure of the value chain, with increasing concentration upstream and downstream, and a hollowing out of the middle of the chain. Vertically integrated suppliers, capable of upgrading from simple production to packing, exporting, and importing, became direct service providers for demanding retail outlets, further consolidating the global supply chain around large, well-financed suppliers.

The extensive adaptations by the fruit and vegetable sector to COVID-19 lockdowns underscore the importance of large agri-food corporations in economic stabilization during crises. Their long-term strategy of building backward and forward linkages may have also played a critical role. Specifically, the firms that led the adaptation of the fresh produce industry were large, multi-product conglomerates from both developed and developing countries like Chile, Peru, South Africa, Morocco, and the Arab Republic of Egypt, all with robust crisis management capabilities. They have decades of experience navigating the uncertainties of weather shocks, diseases, and natural disasters, which they leveraged during the pandemic to maintain operations, adapt to changing market channels,

and implement health and safety upgrades. Importantly, these conglomerates had made strategic investments over more than 20 years aimed at ensuring access to major global markets, adapting to market trends and changing supply conditions, and upgrading their capabilities. These capabilities' upgrades were supported by investments in genetic development, global land acquisition, and the automation and digitalization of processes, creating also comprehensive commercial networks to support their expansive operations.

Motivated by these insights, the ensuing analysis will assess if the fresh produce sector's anecdotal evidence reflects broader trends across other segments of the agri-food industry, as emerging from statistical evidence. This focused quantitative analysis utilizes detailed data to examine agri-food-related firms-to-firm linkages and how these affect resilience and economic performance in the sector. The analysis will probe the key aspects emerging from the fresh produce experience, notably: the role of large agri-food corporations, patterns and significance of firm-to-firm linkages for economic performance, and whether the observed long-term strategy of building backward and forward linkages across different industries and geographies constitutes a model that other segments within the agri-food industry are also adopting.

3 Data and Methodology

3.1 Data

Data on Firm-to-Firm Links The study uses firm-to-firm link data from the FactSet Revere Supply Chain Relationships database, recognized as one of the most comprehensive sources for global firm supply chain information (Huang et al., 2023). This dataset integrates information on a firm's supply chain from various sources, including official firm filings such as 10-K reports submitted to the Securities and Exchange Commission (SEC), along with other filings (8-K, 10-Q forms), as well as investor presentations, press releases,

and company websites (FactSet, 2021).[6] FactSet analysts map the resulting information in consistent records of normalized relationship types, taking into account links detailed in a firm's own records and the records of its partners ("reverse" links). By monitoring additional sources and "reverse" matching links, the database provides an exceptionally comprehensive view of supply chain linkages relative to other databases such as Compustat Segment (Huang et al., 2023).

As of March 2024, the relationship record of more than 54,000 "source" or reporting companies has been actively monitored, yielding a dataset of more than 2 million relationship links that involve approximately 360,000 entities. Table A.3 presents an overview of the list of variables obtained from FactSet. For each link, information on the start and end date is included, with historical data available from 2003. Global coverage starts from 2014, with the latest addition of Latin America in 2016.[7] Furthermore, the nature of each relationship is specified. For our study, we focus on customer and supplier relationships, which we supplement for some of the analysis with information on ownership ties and other firm characteristics. At each point in time, we observe the parent and ultimate parent firm of a company, and if applicable, any subsidiaries.[8] Additionally, the dataset provides information on firm name, industry affiliation, headquarter country, and entity type which we leverage throughout our analysis. Information on the firm's annual sales, converted to constant 2020 U.S. dollars, is added whenever available.

We construct the agribusiness supply chain network by keeping all direct customer or supplier links that involve at least one agribusiness company. We identify this latter based on their primary NAICS 6-digit code, including relevant industries from the agriculture,

[6] In financial reporting, a 10-Q is a company's quarterly report, containing unaudited financial statements, while the 10-K is an extensive annual report with audited financials, executive details, and structure. An 8-K is filed by firms to swiftly update shareholders on unscheduled, important events like management shifts, investigations, deals, closures, layoffs, or bankruptcy, often leading to multiple filings within a quarter for prompt communication. U.S. listed firms must for instance detail any customer that accounts for more than 10% of its revenue (Gofman and Wu, 2022), with some firms voluntarily disclosing additional customers (Huang et al., 2023).

[7] Note that we already observe many records of Latin American source companies in 2014, suggesting a backward updating of relationship for Latin American firms.

[8] The parent or ultimate parent will be identical to the company itself for self-owned firms.

food and beverage manufacturing, fertilizer, pharmaceutical, wholesale and retail, and food services sectors. Table A.4 details the list of NAICS 6-digit codes. We defined the industry broadly given the fact that pharmaceutical companies source many of their ingredients from the agriculture sector, the growing size of the nutraceutical market, and the role of drug stores and general merchandise stores as retailers of processed food.[9] We eliminate a small number of links that are reported to be formed between the same entity and drop linkages that last for less than a day. From this sample, we create a yearly panel of active firm-to-firm connections categorized by relationship type. For the sample period from 2014 to 2022, the dataset contains about 160,000 supplier and customer links, involving more than 17,500 agriculture-related companies and approximately 26,000 non-agri partner firms. More than 4,500 of the agribusinesses are "actively covered", that is they appear as reporting firms in the raw FactSet data.

In general, the number of firm nodes and links in the sample is increasing over time (see Figure A.9, left panel, and Figure A.10). The share of actively covered agribusinesses, non-reporting firm agribusinesses and non-agribusinesses among the set of nodes in a given year is fairly stable (see Figure A.9, right panel). More than 15,000 of the 17,500 agribusinesses are observed during multiple years in the data. About 4000 nodes are observed in all of the nine sample years, approximately 1700 of which are actively covered agribusinesses. Acknowledging the generally increasing size of our network sample, we report some results for the balanced set of firm nodes to study dynamics at the intensive margin.[10]

While the FactSet database offers extensive coverage, it exhibits a potential sample bias towards larger, publicly listed companies due to its reliance on publicly available disclosures. Figure A.11 shows that public companies make up about 25% of all agribusi-

[9]The nutraceutical market refers to the industry centered around foods or food products that provide both nutritional and medicinal benefits. These products, known as nutraceuticals, combine aspects of nutrition and pharmaceuticals.

[10]We are aware that intensive margin link creation might still be influenced by extensive margins entrants and exits, and will keep this possible bias in mind in discussing results.

nesses observed in our dataset, and they are prominently featured in the subset of actively covered businesses. Figure A.12 provides a breakdown of the agribusiness sectors represented in our sample, showcasing the diverse parts of the agribusiness value chain that are included. Regionally, approximately 30% of the agribusinesses are based in the East Asia and Pacific (EAP) region, with North America Europe, and Central Asia having similar representations (see Figure A.13). In the subset of actively monitored agribusinesses, there is an increased proportion of firms from the EAP region at the expense of European and Central Asian firms, while the representation from other regions remains stable. We use the World Bank's geographic classifications for this study, which include the following regions: EAP (East Asia and Pacific), ECA (Europe and Central Asia), LAC (Latin America and Caribbean), MNA (Middle East and North Africa), NAC (North America), SAS (South Asia), and SSA (Sub-Saharan Africa).

To assess the representativeness of our agribusiness sample, we compare the sales data from U.S. agribusiness companies in our FactSet sample to the aggregate U.S. industry output. This comparison, while approximate for a subset of firms, offers valuable insights into the portion of agribusiness activity that our data captures. We derive the information on aggregate U.S. agribusiness output from the Bureau of Economic Analysis, which publishes gross output by industry tables. We ensure comparability between datasets by summing output over the BEA industries that correspond to the NAICS codes used to identify agribusinesses in our sample.[11] However, it's important to note that our method may lead to both overestimating and underestimating the representativeness of

[11] We use the concordances provided by Bureau of Economic Analysis (2023b). We sum over the following BEA industry (groups): Agriculture, forestry, fishing, and hunting; Food and beverage and tobacco products; Fertilizer manufacturing; Pesticide and other agricultural chemical manufacturing; Pharmaceutical and medicine manufacturing; Agricultural implement manufacturing; Grocery and related product wholesalers; Other non-durable goods merchant wholesalers; Building material and garden equipment and supplies dealers; Food and beverage stores; General merchandise stores; Health and personal care stores; Miscellaneous store retailers; Food services and drinking places. Note that the narrowest BEA industry codes "Other nondurable goods merchant wholesalers", "Building material and garden equipment and supplies dealers", "Health and personal care stores", and "Miscellaneous store retailers" include several other NAICS 4-digit codes besides those included in our sample. This leads to an overestimation of U.S. industry output relative to our sample.

our sample. In both cases, however, we show that the coverage remains satisfactory.

There is a risk of underestimating the share of overall industry output covered in FactSet since about only one-fifth of U.S. entities in our FactSet sample have information on sales data available. Aggregating over their sales, thus, may lead to under-representing the actual share of U.S. output observed. In spite of this bias, the coverage is very high. In 2021, the revenue from U.S. agribusinesses with available sales data totaled approximately $4,000 billion—representing about 75%-85% of the total U.S. industry output as per BEA data (see Figure A.14). This share decreases slightly to about 70%-75% when considering only those agribusinesses that are actively reporting in the relationship data each year.

There is also a possibility of overestimating the sales data in our sample compared to the BEA benchmark, as some companies in our sample may report revenues from diverse business segments not directly related to agribusiness.[12] To address this, we adjust for sales from non-agribusiness activities using two approaches: a broad approach that excludes sectors like mining, construction, and services, and a narrow approach that also excludes non-agribusiness manufacturing and trade sales. The broad approach shows a slight reduction in the share of U.S. output represented in our sample, while the narrow approach suggests a coverage ratio of just under 70% for all U.S. agribusinesses with sales data, dropping to around 65% for the subset of actively covered firms.[13]

In conclusion, the above considerations suggest that the FactSet coverage of U.S. agribusinesses is satisfactory, with monitored firms constituting a significant portion of the overall U.S. agribusiness output. This detailed approximation helps frame the scope and scale of our investigation into the agribusiness sector and suggests that our dataset captures a

[12] As entities in our sample are classified based on their primary NAICS code, part of their reported sales might stem from revenues accrued in other business segments. Depending on the BEA's methodology of classifying output from multi-product establishments, this might lead to an overestimation of the sales data reported in our sample relative to the BEA benchmark.

[13] Additional differences and thus under- or overestimation relative to the BEA benchmark can arise from the treatment of cross-border sales depending on the BEA methodology and potentially consolidated reporting for revenues accrued by foreign subsidiaries of the U.S. agribusinesses in our FactSet sample.

substantial share of the industry.

Fortune 500 Companies In some of the descriptive analyses, we complement our firm-to-firm link data with information on the U.S. Fortune 500 agribusiness companies. We sourced these data from the March 2022 list of U.S. Fortune 500 companies, utilizing fuzzy string matching techniques to identify relevant entities in the FactSet database, based on company names and their headquarters' state in the U.S.. We cleaned and reviewed the matching results manually. Table A.5 presents these firms along with their primary industry classifications, offering a detailed view of the leading agribusiness companies that shape our analysis.

3.2 Methodology and Definitions

3.2.1 Descriptive Statistics of the Agribusinesses Network

To assess the role and importance of individual nodes in the agribusiness supply chain network, we primarily rely on the measure of degree centrality. This refers to the combined number of incoming (indegree or supplier) and outgoing (outdegree or customer) ties or links of a node (firm). For a more nuanced understanding, we calculate the weighted degree centrality, where the weights are determined by the duration of activity for each link and the frequency of interactions between two nodes.[14] If an agribusiness maintains two customer and five supplier ties that are active for the entire year, its weighted degree centrality is seven. In some graphs, we distinguished between indegree (i.e., supplier) and outdegree (i.e., customer) links.

Since we are unlikely to observe the complete set of links for firms that only appear as counterparts in other firms' reporting, for more accurate insights, our analysis predominantly focuses on firms that are actively monitored in FactSet. This encompasses

[14]Two nodes can form multiple supplier or customer relationships. An alternative measure is given by the unweighted degree centrality which corresponds to a 0 or 1 dummy indicating whether at least one relationship is active in a given year.

firms whose operational links are well-documented through reliable sources like annual reports, filings, investor presentations, press releases, and company websites. This approach ensures that our data reflects the most complete and accurate representation of each firm's network interactions.

Additionally, we explore the dynamics of external versus internal corporate relationships by examining the number of entities connected to a firm through ownership ties, which include subsidiaries, parent companies, and other affiliates within the same corporate family. This captures all other entities that share the same ultimate parent in a given year.[15] We also consider the relevance of these connections to the agribusiness sector by identifying corporate family entities whose primary industry aligns with agribusiness criteria, providing a more targeted estimate of industry-specific within-corporate family interactions in some of the analyses. We consider this metric a lower estimate of the number of entities that an agribusiness company engages with within its corporate boundaries.

3.2.2 Exit Dynamics

In the final step of the analysis, we investigate the correlation between a firm's network centrality and its exit probability from the agri-business network. Specifically, we apply a logit regression model to the subset of agribusinesses that are actively monitored and have available sales data:

$$logit(P_{ft}) = \alpha + \beta log(wgt.degree_{ft-1}) + \gamma log(sales_{ft-1}) + \theta_t + \epsilon_{ft} \quad (1)$$

[15]Related firms can consist of a firm's subsidiaries, a firm's parent, its parent's parent, or other subsidiaries of its ultimate parent. If a firm changes its ultimate parent in a given year, the firm family to which the firm belonged for the majority of the year is taken as a reference count. Non-firm entity types are excluded from the count: Aircraft, Commodity, Currency, ForEx, Index, Individual, Broadcast Call Sign, Asset-Backed, Bank Branch, Corporate Assets, Emp Stk Ownership Plan, Family of Fds (VC/Pvt EQ), Hedge Fund, Mutual Fd-Closed End, Mutual Fd-ETF, Mutual Fd-Open End, Pension Fund, Real Property, Port, Ship. The following entity types are included: Business Association (JP), College/University, Extinct, Foundation/Endowment, Financing Subsidiary/SPE, Government, Holding Company, Joint Venture, Non-Profit Organization, Operating Division, Public Company, Private Company, Subsidiary.

Here P_{ft} denotes the probability of a firm f exiting the network in year t, $log(wgt.degree_{ft-1})$ represents the logarithm of the firm's weighted degree centrality from the previous year $(t-1)$, and $log(sales_{ft-1})$ is the logarithm of the firm's annual revenue, adjusted to constant 2020 USD, from the previous year. In some specifications, the model also includes year-fixed effects (θ_t) to account for time-specific variations and a dummy variable to capture different types of linkages.

We define exiters as firms that are no longer observed in our dataset in subsequent years, indicating their departure from the sample. This model helps in understanding how a firm's connectivity and economic performance influence its stability and longevity within the agribusiness network.

4 Results

This section presents the results of the analysis proposed in Section 3. Our first step involves a descriptive assessment focused on the role of U.S. Fortune 500 relative to non-Fortune 500 firms within the agri-food value chains. These lead firms are found to be not only more interconnected but also increasingly central to the agro-food global value chains (GVCs). Intriguingly, post-2018, there is a noticeable trend of these corporations consolidating activities within their corporate boundaries, contrasting with the expansive strategies of non-U.S. firms. Building on these findings, we extend our analysis to a systematic examination of firm-to-firm connectivity across all firms in the FactSet database related to the agri-food sectors. Here, we uncover that highly connected firms not only increase their customer and supplier base over time but also maintain central roles within the network without diversifying their core relationships within their primary industries. Moreover, we explore the broader implications of these connectivity patterns on firm longevity and success through an empirical investigation into the factors influencing a firm's likelihood of exiting the industry. This multifaceted analysis highlights some im-

portant critical trends.

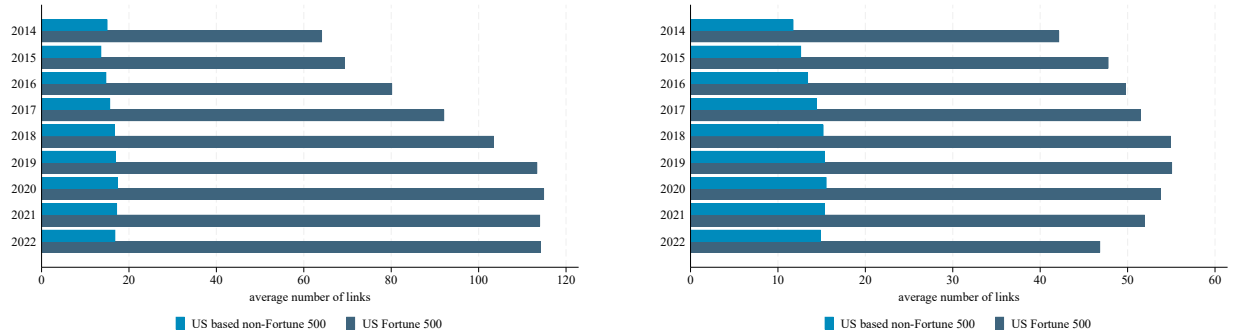
4.1 U.S. Fortune 500 Firms Role in the Agribusiness Industry

The increasing centrality of U.S. Fortune 500 companies within the U.S. agricultural-food value chains illustrates a significant evolution in food systems. As evidenced by data reflecting their degree centrality — a measure based on the number of direct customer and supplier relationships - these firms have established more robust and numerous connections compared to their non-Fortune 500 U.S.-based counterparts (see Figure 1, left panel).[16] From 2014 to 2019, Fortune 500 companies not only expanded their networks but also became relatively more integral to the agro-food global value chains (GVCs).[17] This rise in centrality indicates a trend towards greater influence and control within the sector. Re-computing degree centrality on the balanced set of firm nodes suggests that this increase is partly attributed to changes in the sample, including the entry or exit of firms, thereby highlighting the dynamic nature of these networks and the growing dominance of major corporations in shaping the agricultural and food industries (see Figure 1, right panel).

[16] This is confirmed by a non-parametric Wilcoxon rank sum test which suggests that the number of links of U.S. Fortune 500 agribusinesses and other U.S. firms is significantly different from each other at the <1% level.

[17] A Wilcoxon rank sum test which compares the number of links for Fortune 500 companies in 2014 to the number of links in 2022 suggests a statistically significant difference, while the hypothesis of the number of links being drawn from the same distribution in 2014 and 2022 cannot be rejected for U.S. non-Fortune 500 firms.

Figure 1: Centrality of Fortune 500 Agribusiness Companies



Note: The graph shows the average number of customer and supplier links ("degree centrality") for actively covered U.S. Fortune 500 agribusiness companies and other U.S. firms over time. Fortune 500 agribusinesses are identified from the March 2022 list of U.S. Fortune 500 companies. The left graph depicts the degree centrality of actively covered enterprises based on their links to all firms observed in the network in a given year, the right graph depicts the degree centrality of actively covered enterprises while including only links between firms that are constantly observed in the sample (that is excluding any entrants or exiters between 2014 and 2024).

Recent data reveal a strategic shift among U.S. Fortune 500 companies, with a discernible focus since 2018 towards strengthening intra-corporate linkages—particularly ownership ties—over external customer and supplier relationships. This shift towards internal consolidation is clearly illustrated in Figure 2 (left panel), which demonstrates a notable increase in ownership-related ties, all consolidated under the same ultimate parent entity, within these prominent corporations. The trend is visible both at the average (upper left panel) and at the median (lower left panel). While U.S. non-Fortune 500 and agri-food firms from the rest of the world also exhibit an increase in ownership-related affiliations by 2021, the growth in these connections significantly lags behind their expansions in supplier and customer links, especially when analyzed at the median level. This indicates a more subdued inclination toward internal network densification among either smaller corporations or non-U.S. firms.[18] Moreover, the rise in ownership links among U.S. Fortune 500 companies within the agribusiness sector closely tracks their increase in traditional business connections, suggesting a strategic integration of their corporate structure with their primary business operations. In stark contrast, such internal connec-

[18] Analyzing the subset of smaller U.S. corporations in Figure 3 below suggests that the subdued internal network densification is driven by non-U.S. corporations.

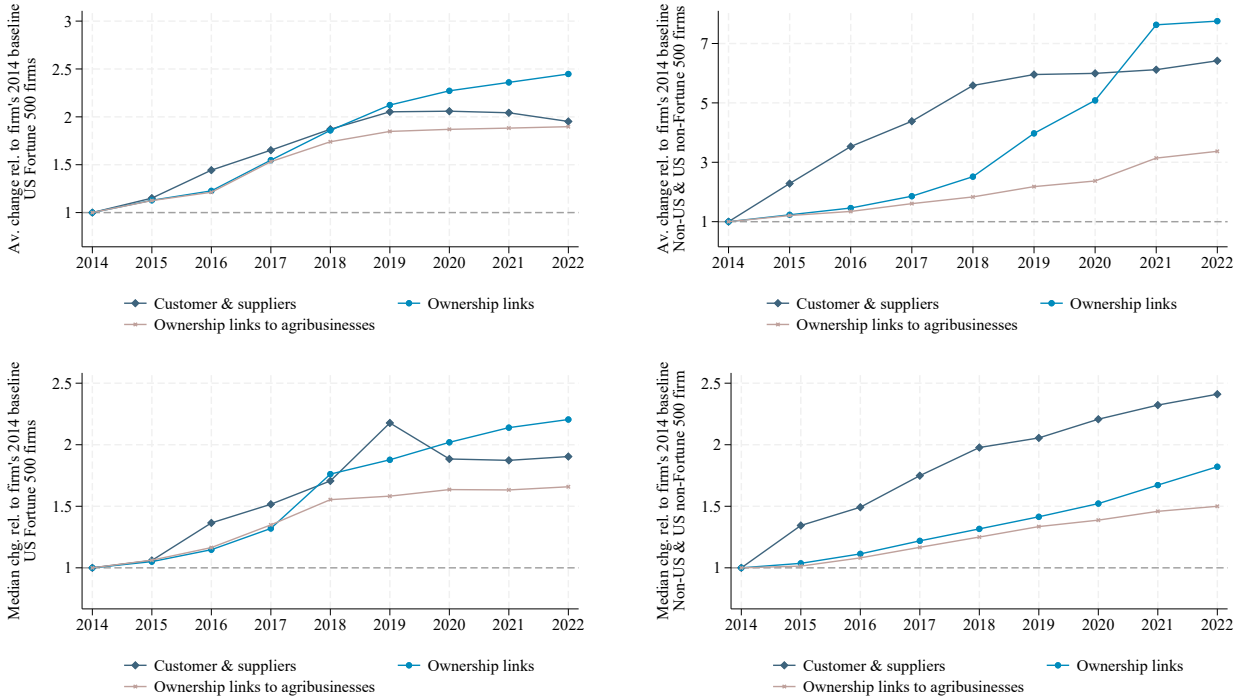
tions in the agribusiness context for the rest of the agribusiness firms remain considerably smaller.

It is noteworthy that while the average relative increase in linkages is more pronounced among firms other than the Fortune 500 U.S. entities in our sample, the median increases are more subdued, suggesting a skewed distribution of relative increases. For U.S. Fortune 500 companies, the average and median relative change tend to fall in a similar range. Furthermore, as shown in Figure 1, the actual level of supply chain connectivity remains much higher among the U.S. Fortune 500, highlighting their greater organizational complexity and perhaps a strategic move towards more controlled, integrated operations.[19] Note that this analysis purposely omits entities without initial ownership links in 2014 to focus on changes among already interconnected firms.[20] Additional graphs focusing solely on U.S. non-Fortune 500 firms, presented in Figure 3, reveal a substantial relative increase in ownership. This reinforces the significance of examining the global agri-business production network rather than focusing solely on the dynamics of even important, single markets in future discussions.

[19] Figure A.16 shows the equivalent comparison of U.S. Fortune 500 agribusiness to all other actively covered firms in our sample (non-U.S. based firms and non-Fortune 500 U.S. firms).

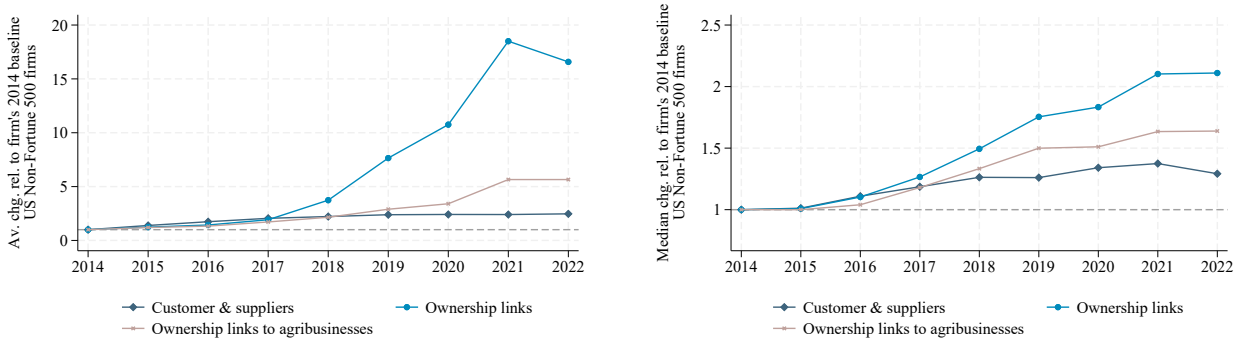
[20] The bottom panel of appendix figure A.15 shows the share of non-U.S. and non-Fortune 500 U.S. entities with zero ownership ties or no agribusiness in their corporate family in a given year. All but one constantly observed U.S. Fortune 500 agribusiness have at least one ownership tie and at least one other agribusiness within their corporate family. The upper and middle panels of appendix figure A.15 show results for Figure 2 and Figure 3 when including only firms with non-zero ties for both, general ownership ties, and ownership ties to agribusinesses, in 2014. This leaves our findings almost unaltered.

Figure 2: External Links vs. Ownership Integration



Note: This graph compares the evolution of a firm's number of customers and suppliers to the number of firms that it is linked to via ownership ties (either parent, subsidiary, or common parent). For each firm, the change in the number of externally and internally connected firms is computed relative to its 2014 value, before taking the average over U.S. Fortune 500 agribusiness companies (left graph) and non-U.S. based or non-Fortune 500 U.S. agribusiness companies (right graph). The upper panel shows the yearly average, and the lower panel shows the median relative change to 2014 for the sample of firms. Constantly observed actively covered companies are included. By construction, firms with no ownership links in 2014 are dropped (equivalent for the series depicting relative changes of agribusinesses in a firm's corporate family).

Figure 3: External Links vs. Ownership Integration (U.S. non-Fortune 500 Entities)



Note: This graph compares the evolution of a firm's number of customers and suppliers to the number of firms that it is linked to via ownership ties (either parent, subsidiary, or common parent). For each firm, the change in the number of externally and internally connected firms is computed relative to its 2014 value. The left panel shows the yearly average for U.S.-based non-Fortune 500 firms, and the right panel shows the median. Constantly observed actively covered companies are included. By construction, firms with no ownership links in 2014 are dropped (equivalent for the series depicting relative changes of agribusinesses in a firm's corporate family).

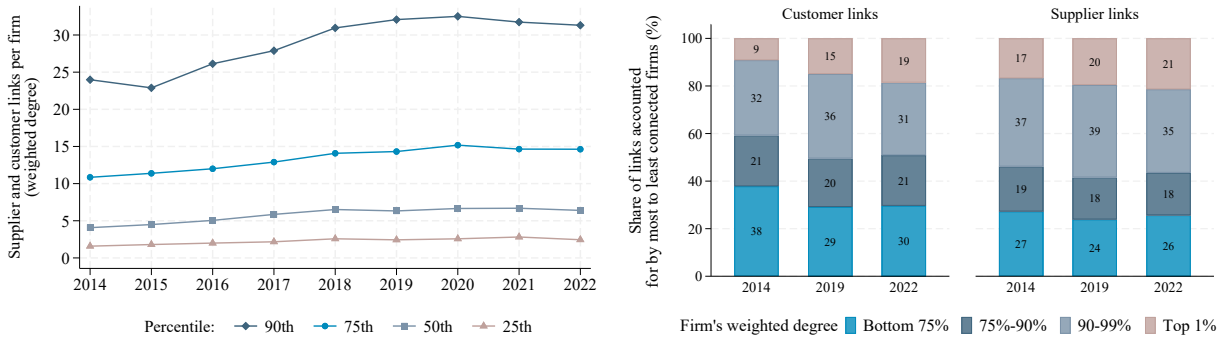
4.2 The Global agri-food Network

Our analysis of the broader global agri-food industry confirms that the most connected firms are not only maintaining but significantly increasing their network of customers and suppliers over time. This trend underscores the pivotal roles that few highly connected firms play within the network, affirming their central position in the agribusiness industry's connectivity landscape. Figure 4 provides a vivid illustration of this dynamic. The left panel of the figure reveals a relatively stable number of links for the bottom percentiles of firms in the degree distribution over time, indicating minimal change in connectivity among less connected firms. However, there is a marked and sharp increase in the number of links at the 90th percentile, highlighting that the most connected firms in a given year are ever more connected than their less-connected counterparts. The right panel of Figure 4 further elucidates the dominance of these top-tier firms, showing a significant share of the direct customer and supplier links in the agribusiness network attributable to firms from the highest percentiles in terms of degree distribution. This suggests that a small set of highly connected firms not only maintains but also intensifies their influence on the overall network structure over time.

Additional insights are provided in Figure 5, which tracks the average number of links for a balanced sample of actively covered agribusiness companies, categorized by their 2014 percentile in the link distribution. This longitudinal perspective reaffirms the growing disparity in connectivity, emphasizing the widening gap between the most connected firms and the rest. The most connected firms in 2014 expanded their networks at a much faster rate, relative to firms below the 90th percentile. This is visible for both, the average firm above the 90th percentile (left panel), as well as the median firm (right panel).[21]

Together, these findings depict a clear and continuing trend of degree centralization within the agribusiness network, with a few highly connected firms increasingly dictating the flow and structure of industry interactions. This centralization may have profound implications for market dynamics, competitive strategies, and the distribution of influence within the agribusiness sector.

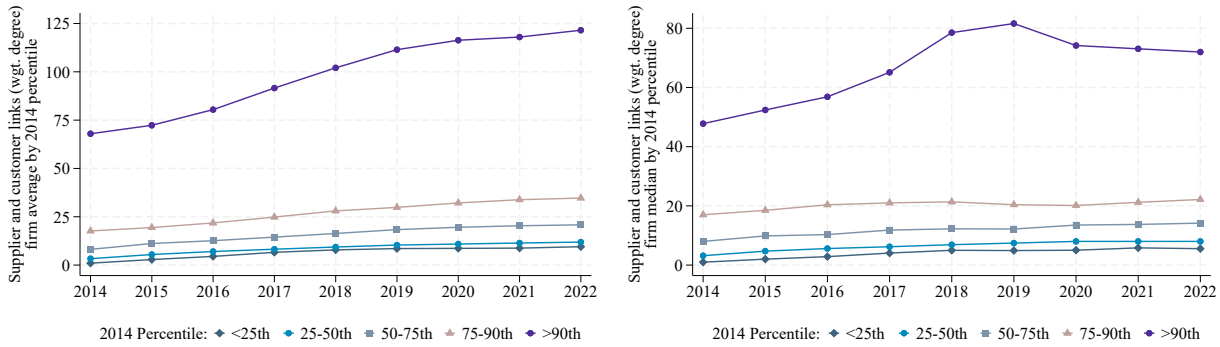
Figure 4: Distribution of Firm Links



Note: The left graph depicts the 25th, 50th, 75th, and 90th percentile of the average number of supplier and customer links (weighted degree) per firm in a given year. The sample includes agribusiness firms that are actively covered in a given year (e.g. appear as source companies in at least one record). The right graph shows the share of the customer (supplier) links by "connectedness" (weighted firm degree) of the supplier (customer) firm for 2014, 2019, and 2022. All links of actively covered agribusiness companies are included. A supplier link denotes a link where the partner firm is a supplier of the agribusiness firm, and vice versa for a customer link.

[21] As a robustness check, Figure A.17 focuses on links between continuing firms (i.e. firms observed in the sample throughout the entire period), offering a refined view of enduring relationships and highlighting sustained connectivity patterns among stable entities in the sector.

Figure 5: Evolution of Weighted Firm Degree by 2014 Percentile



Note: The graph tracks the average (left panel) and median (right panel) number of links for firms in the bottom 25th percentile, the 25th-50th percentile, the 50th-75th percentile, the 75th to 90th percentile, and above the 90th percentile of the weighted degree distribution (i.e. the firm link count) in 2014 over time, focusing on the balanced sample of actively covered agribusiness firms.

Our findings also indicate signs of strategic diversification and concentration. Within narrowly defined industries, agribusiness firms maintain a stable number of relationships and do not exhibit a tendency to diversify these specific relationships (see top and bottom left panel, Figure 6. Instead, these firms demonstrate a strategic pattern of maintaining a constant number of firms per partner-industry, for both customer and supplier connections. This observation suggests a preference for deepening existing relationships rather than expanding their network within the immediate industry sectors of their partner firms.

Conversely, there is a clear trend toward industry diversification, as evidenced by the increasing number of distinct industries to which firms maintain supplier or customer relationships. This trend is illustrated in the left panels of Figure 6, which show a steady rise in the variety of industries connected to these firms over time, both for the full sample of actively covered agribusiness (upper left panel) and the balanced subset of firms (bottom left panel).

Further insights from the balanced sample of agribusinesses, as shown in the right bottom panel of Figure 6, indicate a tendency to increase the number of partner countries and firms per partner country. This finding highlights the firms' efforts to expand their international footprint, despite some fluctuations in the share of firms with international

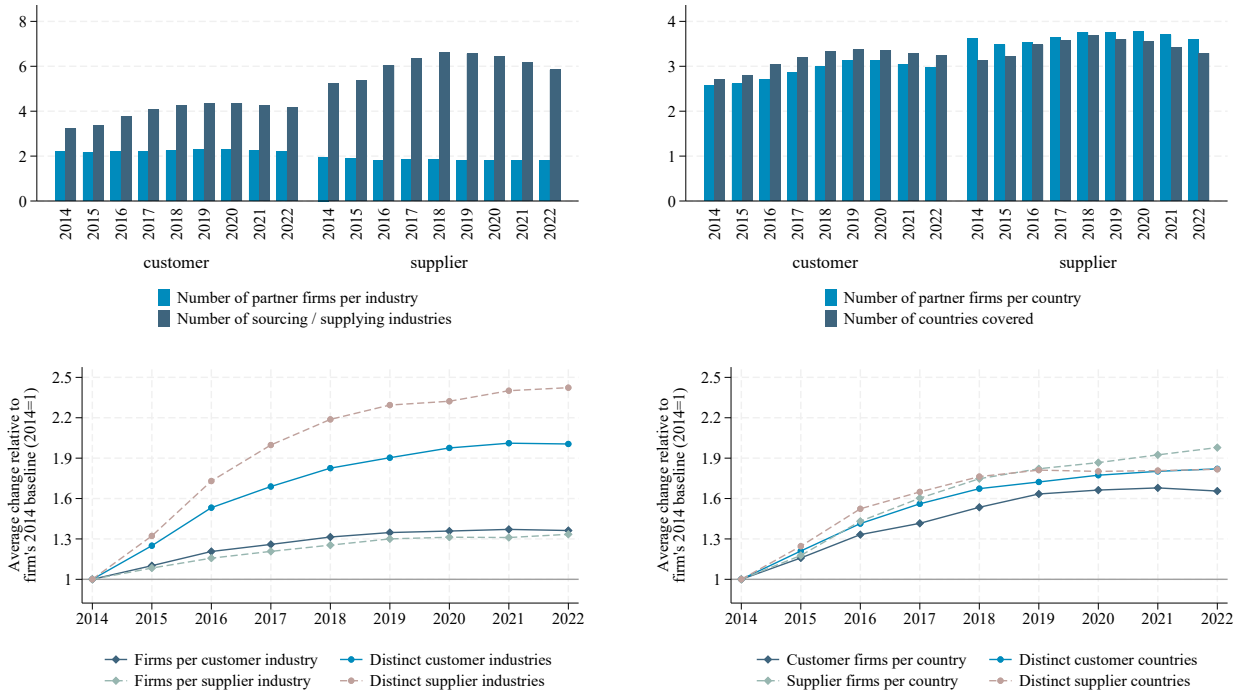
links, as depicted in the upper panel Figure 7. Notably, firms with at least one international link tend to maintain more numerous connections, with an increasing average number of links throughout our sample period, as shown in the lower panel of Figure 7.[22] [23]

These dynamics suggest complexity in firms' strategic approach: while these firms solidify and concentrate their core supply relationships, they simultaneously seek to diversify their market presence, aiming to mitigate risks and capitalize on emerging global opportunities. This dual strategy of concentrated supply and diversified demand mirrors broader trends in global trade and business strategy, emphasizing the importance of flexibility and adaptation in the rapidly evolving agribusiness sector.

[22] When analyzing a firm's global footprint, we distinguish between three types of links: domestic links, regional links, and cross-regional links. We then categorize firms into those that form only domestic but no international links, those that are involved in within-region linkages but not in cross-regional activities, and those that have at least one cross-regional link. Regions correspond to the seven World Bank geographic regions as detailed in the figure notes of Figure 7.

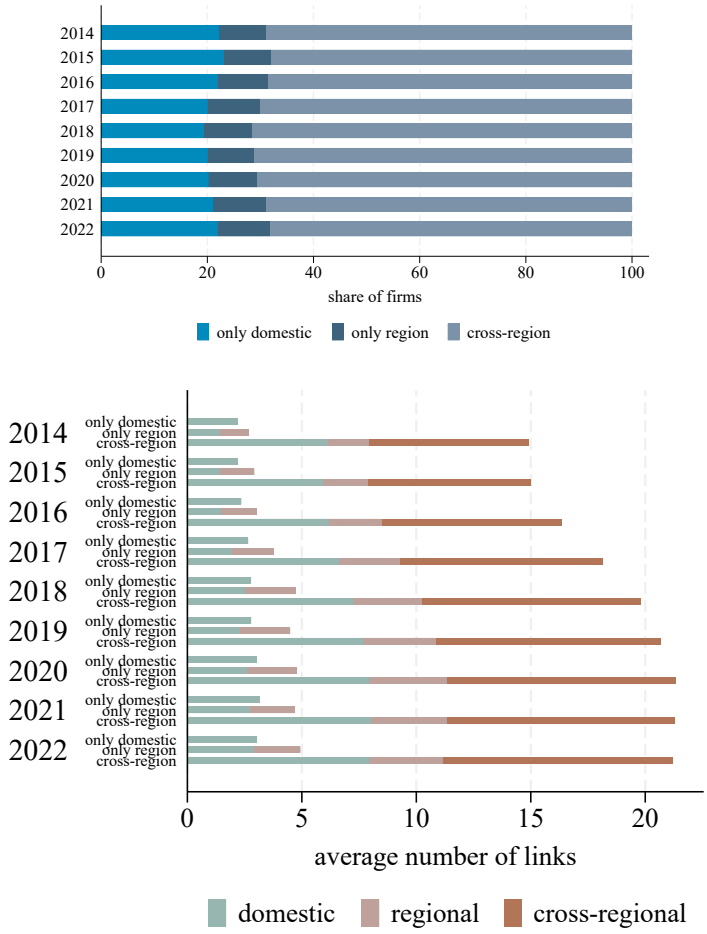
[23] A non-parametric Kruskal-Wallis test, a multi-sample application of the Wilcoxon rank sum test, suggests a statistically significant different link distribution between only domestic, only regional, and cross-regionally active firms at the $<1\%$ level. All three pairwise comparisons tested with the Wilcoxon test confirm this observation. Furthermore, the 2014 links distribution is statistically and significantly different from the 2022 link distribution for all three firm types, according to separately conducted Wilcoxon tests.

Figure 6: Supply Chain Complexity and Depth



Note: The top left graph shows the average number of suppliers (customers) per NAICS 6-digit industry (light blue bars) for the sample of actively covered agribusiness companies for 2014 to 2022, as well as the average number of industries to which the firm maintains direct customer or supplier links in a given year (dark blue bars). The top right graph shows the average number of suppliers (customers) per country (light blue bars), as well as the average number of countries to which the firm maintains direct customer or supplier links in a given year (dark blue bars). Partner firms without industry affiliation and missing headquarter countries are excluded. The bottom left graph focuses on a balanced sample of actively covered agribusiness companies, thus excluding entrants and exiters after 2014. It shows the average over firm's change in their number of partner firms (supplier/customer) per industry, and the number of industries that its partner firms are affiliated to, relative to 2014. The bottom right graph depicts the relative change in the number of countries in which the firm is active as a supplier or customer, as well as the number of customer or supplier firms per country.

Figure 7: Firms Global Footprint



Note: The upper graph shows the share of actively covered agribusiness companies with only domestic links, also regional but not cross-regional, or cross-regional links. The bottom graph shows the average number of links of a purely domestic, only regional, or cross-regionally active firm. It further splits the average number of links into domestic, regional, and cross-regional supply chain ties. By construction, purely domestic firms are not involved in any international links and only regional firms are not engaged in any cross-regional links. Regions correspond to the seven World Bank geographic regions: EAP (East Asia and Pacific), ECA (Europe and Central Asia), LAC (Latin America and Caribbean), MNA (Middle East and North Africa), NAC (North America), SAS (South Asia), and SSA (Sub-Saharan Africa).

4.3 Linkage Dynamics and Firm Exits in the Agri-food Industry

To harness the potential of our dataset, the last part of our analysis delves into the influence of various types of linkages on the likelihood of firms exiting the agri-food industry. By categorizing linkages based on their backward and forward integration, geographic reach, and nature, we explore how these factors correlate with firm stability. Our findings consistently show that firms with a greater number of linkages are generally less likely to exit the industry, suggesting that robust network connections play a crucial role in sustaining business operations.

Our regression analyses, synthesized in the Table 1 below, provide a clear picture of how different types of linkages impact firm stability. Columns (1) and (2) show the results for the regression specification detailed in Equation 1. Both the specification without and with year-fixed effects suggest a statistically significant correlation between firm linkages and exit. The higher the number of linkages in the previous year, the lower the exit probability in the subsequent year. Column (3) consolidates supplier and customer relationships into a single categorical variable, differentiating firms that have only customer links, only supplier links, or both. Notably, the presence of both customer and supplier linkages is a significant factor in reducing the probability of exiting the industry, indicating the critical role of diverse business connections in enhancing firm resilience.

However, other heterogeneity analyses, including international ties (column (4)), agri-specific ties (column (5)), and ownership links (column (6)), do not yield significant results, suggesting that not all types of linkages equally contribute to decreasing the exit probability. This finding confirms the complexity of network effects in the agri-food sector. Probing different specifications to account for heterogeneity in ownership ties in columns (1) to (4) of Table 2 confirm the finding in column (6) of Table 1. While supply chain linkages consistently appear to be negatively associated with firm exit, no statistically significant relation is found for ownership ties. Using unweighted instead of weighted counts of supply chain linkages, that is a simple dummy count for two firms

being connected in a given year, or studying the correlation for two-year rather than one-year lags leaves our main finding unaltered (see columns (5)-(8) in Table 2).

Table 1: Firm Linkages and Exit Probability

	Exit						Exit Extinct Parent exit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log wgt. degree (t-1)	-0.301***	-0.289***	-0.137	-0.293***	-0.263**	-0.287***	-0.203***
	(0.087)	(0.092)	(0.111)	(0.099)	(0.104)	(0.093)	(0.079)
has only supp. ties (t-1)			-0.602*				
			(0.340)				
has cust. & supp. ties (t-1)			-1.138***				
			(0.319)				
has international ties (t-1)				0.033			
				(0.308)			
has agri ties (t-1)					-0.212		
					(0.328)		
has owner ties (t-1)						-0.234	
						(0.369)	
log sales (t-1)	-0.131***	-0.132***	-0.118***	-0.131***	-0.132***	-0.124***	
	(0.043)	(0.042)	(0.044)	(0.042)	(0.042)	(0.047)	
Observations	18488	18488	18488	18488	18488	18488	21419
Year FE		✓	✓	✓	✓	✓	
Num exiters	63	63	63	63	63	63	26

Note: This table illustrates the relationship between exit probability and firm degree (number of direct linkages). Exiting firms are entities which are not observed in any subsequent year during our sample period. Columns (1)-(6) include a control for log pre-period annual revenue, measured in constant 2020 U.S. dollars. Columns (2) to (6) include year-fixed effects. The omitted category in col (3) equals one for firms with only customer ties in (t-1), relative to those with only supplier or both customer and supplier links. Column (4) includes a dummy variable that equals one if a firm has international (non-domestic) links in (t-1). Column (5) includes a dummy equal to one for firms that maintain a supply chain link to another agribusiness company in (t-1). Column (6) includes a dummy variable equal to one if a firm has ownership-links in in (t-1). Column (7) applies the restrictive definition of exiters being firms that exit our sample in a given year, which are marked as extinct by the data provider as of March 2024, and whose parent also exits the data (all subsidiaries, if any, of the ultimate parent of the exiting firm and, if applicable, the ultimate parent itself exit the data). Robust standard errors are applied.

Additionally, the robustness of our results is affirmed even under conservative definitions of firm exit, where the sample size narrows significantly. For instance, our sample of firms considered as exiters diminishes drastically when using a stringent definition of exit (i.e. firms labeled as extinct by FactSet whose ultimate parent, including all subsidiaries, if any, also exits the data). Despite this reduction, the negative relationship between the

number of lagged links and the probability of exit remains significant when excluding the sales controls, as detailed in column 9 of Table 1.[24] This robustness check, alongside the graphical evidence presented in Figure 8, illustrates the enduring impact of linkage density on firm longevity.

Table 2: Firm Linkages and Exit Probability: Alternative Specifications

	Exit							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log owner ties (t-1)	0.011	0.042	0.042					
	(0.098)	(0.091)	(0.091)					
log wgt. degree (t-1)		-0.300***	-0.282***	-0.288***				
		(0.100)	(0.106)	(0.093)				
has owner ties to agri (t-1)				-0.046				
				(0.303)				
log unwgt. degree (t-1)					-0.463***	-0.453***		
					(0.154)	(0.156)		
log wgt. degree (t-2)							-0.257**	-0.242**
							(0.106)	(0.107)
log sales (t-1)	-0.172***	-0.171***	-0.172***	-0.129***	-0.110**	-0.112***		
	(0.055)	(0.056)	(0.054)	(0.047)	(0.044)	(0.042)		
log sales (t-2)							-0.137***	-0.136***
							(0.048)	(0.047)
Observations	16532	16532	16532	18488	18488	18488	15168	15168
Year FE			✓	✓		✓		✓
Num exiters	52	52	52	63	63	63	50	50

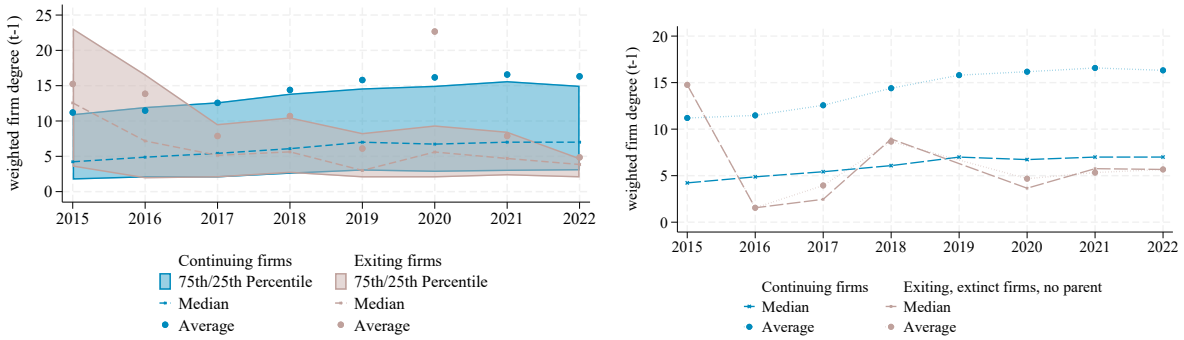
Note: This table illustrates the relationship between exit probability and firm linkages. Exiting firms are entities which are not observed in any subsequent year during our sample period. All columns include a control for log pre-period annual revenue, measured in constant 2020 U.S. dollars. Columns (7) to (8) use the two-period lag. Columns (3), (4), (6), and (8) include year fixed effects. Column (1)-(3) test for a relation between the number of ownership-connected firms and firm exit, including the variable for supply chain linkages from column (2). Column (4) replaces the log owner ties variable with a dummy equal to one if a firm has ownership linkages to an agribusiness. Columns (5) and (6) replace the weighted degree measure with the unweighted degree count, i.e. a simple dummy for two firms being connected in a given period. Columns (7) and (8) show the specification with two rather than one lags. Robust standard errors are applied.

Overall, our findings highlight the importance of a well-connected network in mitigating the risks associated with potential industry exit, providing essential insights for firms

[24] We observe a total of 28 extinct exiters without surviving ultimate parent. This number reduces to 26 when considering lagged links. Only three of these firms have available sales data, limiting the feasibility of statistical inference.

aiming to fortify their market position and ensure long-term viability in the agri-food sector.

Figure 8: Exiters vs. Continuing Firms



Note: The left panel displays the 25th, 50th, and 75th percentiles, as well as the average number of supplier and customer links for exiting and continuing firms. The sample comprises actively covered agribusiness firms in a given year, meaning firms that appear as source companies in at least one record. Exiting firms are entities which are not observed in any subsequent year during our sample period. We observe a total of 253 exits in our sample of actively covered agribusinesses. The right panel shows the average and median for a very restrictive definition of exiters. Exiters are identified as actively covered agribusinesses that exit our sample in a given year, which are marked as extinct by the data provider as of March 2024, and whose parent also exits the data (all subsidiaries, if any, of the ultimate parent of the exiting firm and, if applicable, the ultimate parent itself exit the data). We observe a total of 28 extinct exiters without surviving ultimate parent. Given the small number of exiters per year for the restrictive exit definition, we only show averages and medians in the right panel.

5 Discussion

This section delves deeper into our findings, linking them to existing literature and outlining potential avenues for future research. A significant contribution of this study is the demonstration that the probability of firms exiting the agri-food industry inversely correlates with the robustness of their networks. Firms with diverse customer and supplier links are notably less likely to exit the industry, highlighting the critical role of strong network connections in enhancing firm resilience and longevity.

However, not all linkages exert the same influence. Recent research on the US agribusiness sector reveals that while horizontal diversification strengthens resilience, vertical diversification may weaken it (Stevens and Teal, 2024). This distinction underscores the

complexity of diversification strategies and their varied impact on supply chain robustness, suggesting a fertile ground for further exploration. Our analysis distinguishes between different types of links—customer, supplier, and ownership—and confirms that not all are equally influential in preventing firm exits. Customer and supplier links are crucial, but the distinctions between international or domestic, agri-specific or broader industry linkages merit additional investigation.

Market conditions may also significantly influence link formation decisions. For instance, recent studies, such as Michelson (2017), highlight that in Low and Middle-Income Countries (LMICs) the participation of neighboring farmers can dissuade a farmer from joining the supermarket supply chain. This finding suggests that contractual terms for early entrants in these markets may be less favorable compared to those granted to those who join later. Such dynamics stress the importance of considering market conditions in LMICs when analyzing the impact of network resilience on firm stability, providing deeper insights into strategic decisions within networks.

Notably, our study highlights the distinctiveness of certain firms. The most connected firms—particularly those at the 90th percentile and above—are not only maintaining but also significantly increasing their number of customer and supplier relationships. A key insight from our study is that a small set of highly connected firms continues to occupy central positions within the agri-food global value chains. These observations resonate with findings from prior studies on firm networks and agricultural value chains, supporting the theory of increased link concentration among top firms as theorized in network formation literature (Barabási and Albert, 1999; Sargent and Stachurski, 2024; Gabaix, 2011). In addition, Oberfield (2018) finds similar dynamics in a paper in which the network structure of production is endogenous. Further empirical studies (Alfaro-Urena et al., 2022; Bacilieri et al., 2023; Cardoza et al., 2020) corroborate these trends. Moreover, Giovannetti and Marvasi (2016) illustrate how network expansion through major supermarket chains enhances the participation of small agri-food producers in international

markets, boosts their exports, and contributes to network growth predominantly driven by large firms. Each of these research streams provides valuable insights into the broader effects of high connectivity within industry networks. However, whether this concentration is endogenous to network growth or a result of shifting market trends remains an open question and an intriguing direction for future research.

In our paper, we argue that the observed patterns of concentration and diversification are noteworthy and may reveal evidence of strategic diversification. In particular, we find evidence of a dual strategy by firms which involves maintaining stable, concentrated supply relationships while diversifying customer and supplier bases across different regions and industries. In other words, despite a concentration of supply chain relationships with established partners within the same industries, firms exhibit a notable trend toward industrial diversification into new industries and geographic expansion. Such a finding is novel and intriguing, deserving further exploration. Some studies offer some indirect evidence of such strategic diversification within supply chains, noting that although the industry spectrum is expanding, the number of suppliers and buyers per industry remains constant, even as significant turnover in relationships occurs. This pattern is highlighted for example in research by Huneeus (2018); Martin et al. (2020). Future investigations should examine these dynamics more deeply, to assess whether they genuinely reflect strategic diversification or are influenced by other factors, and to determine if they are specific to certain geographical regions, income levels, and types of firms.

The finding of a possible strategic expansion of sourcing by agri-businesses across a broader spectrum of industries is particularly crucial and relevant for LMICs, where there is a noticeable lack of backward and forward linkages between agri-businesses and other sectors of the economy. Lack of linkages for example is consistent with the finding that although LMICs are increasingly integrated into international agricultural markets, most locally produced food is consumed domestically, and intermediary processed food products often fail to meet international standards (Dries and Swinnen, 2004; Barrett et al.,

2022).

The strategic expansion observed may also be driven by vertical integration, where major firms increasingly act as consumer-facing service providers. Our study offers initial insights, by documenting the evolution of a firm's number of external customers and suppliers relative to its ownership-linked firms. This represents an aspect of the data that is particularly unique. We highlight a notable trend: since 2018, Fortune 500 firms in the United States have increasingly turned their focus inward, emphasizing ownership-linked networks over external partnerships with customers and suppliers. This shift toward more centralized, integrated operations within these corporations suggests a strategic pivot that may however be more prevalent in the U.S. than elsewhere.

Further detailed examination of these patterns, especially whether they reflect strategic diversification or are driven by other determinants, is essential. Moreover, although our findings suggest that these patterns might extend to LMICs, offering a potential pathway to enhanced economic development and sectoral integration, specific investigations into different countries are necessary to confirm this hypothesis.

In conclusion, this paper not only aligns with but also builds upon existing research, offering new insights into the dynamics within Global Value Chains in the agri-food sector. The suggested research directions can deepen our understanding and highlight critical areas for policy refinement and business strategy development, particularly in emerging markets where such insights are most urgently needed.

6 Conclusion

This paper investigates the evolution and resilience of global value chains (GVCs) in the agri-food sector amid global disruptions such as trade wars, pandemics, and environmental crises. Utilizing unique data from the FactSet database and a comprehensive list of Fortune 500 firms, we analyze around 17,500 agri-food companies and over 150,000

supplier and customer relationships globally from 2014 to 2022.

Our findings reveal that highly connected firms not only maintain but also significantly enhance their supplier and customer networks, reducing their risk of industry exit and boosting resilience. However, the protective effects of these linkages vary, underscoring the importance of strong, diverse connections for firm longevity.

We note a significant trend of link centralization within the agribusiness network, where a small number of firms increasingly dictate the flow and structure of industry interactions. This observation supports a strategic model of "concentration of supply and diversification of demand," where firms consolidate their supply chains within a few trusted relationships in their core industry while expanding across diverse industrial sectors and geographical areas.

The strategic expansion of sourcing by agri-businesses across a broader range of industries is particularly critical for enhancing linkages in LMICs' agri-food sectors, which often suffer from limited backward and forward connections. Determining whether this expansion is driven by vertical integration, turning suppliers into consumer-facing providers, or other diversification strategies, requires further exploration. Additionally, more research is needed into the geographic, strategic, and market-structure implications of these trends.

Our dataset also provides new insights into the evolution of firms' external customer and supplier numbers relative to their ownership-linked entities, revealing complexities beyond traditional market-based transactions.

These insights have significant policy and strategic implications, particularly for enhancing the stability and resilience of agri-food GVCs. Policies that foster robust network connections and support firm adaptability can help stabilize global agri-food supply chains while understanding these strategic linkages can guide firms in strengthening their positions within the GVCs, thus enhancing their economic sustainability and resilience against global shocks.

References

Alfaro, L. and Chor, D. (2023). Global supply chains: The looming "great reallocation". Technical report, National Bureau of Economic Research.

Alfaro-Urena, A., Manelici, I., and Vasquez, J. P. (2022). The effects of joining multinational supply chains: New evidence from firm-to-firm linkages. *The Quarterly Journal of Economics*, 137(3):1495–1552.

Amendolagine, V., Presbitero, A. F., Rabellotti, R., Sanfilippo, M., and Seric, A. (2017). Fdi, global value chains, and local sourcing in developing countries.

Ando, M. and Hayakawa, K. (2022). Does the import diversity of inputs mitigate the negative impact of covid-19 on global value chains? *The Journal of International Trade & Economic Development*, 31(2):299–320.

Antràs, P. (2020). De-globalisation? global value chains in the post-covid-19 age. Technical report, National Bureau of Economic Research.

Arita, S., Grant, J., Sydow, S., and Beckman, J. (2022). Has global agricultural trade been resilient under coronavirus (covid-19)? findings from an econometric assessment of 2020. *Food Policy*, 107:102204.

Bacilieri, A., Borsos, A., Astudillo-Estevez, P., and Lafond, F. (2023). Firm-level production networks: what do we (really) know. *Unpublished results, University of Oxford*.

Baldwin, R. and Freeman, R. (2020). Trade conflict in the age of covid-19. *VoxEU. org*, 22.

Balié, J., Del Prete, D., Magrini, E., Montalbano, P., and Nenci, S. (2019). Does trade policy impact food and agriculture global value chain participation of sub-saharan african countries? *American Journal of Agricultural Economics*, 101(3):773–789.

Barabási, A.-L. and Albert, R. (1999). Emergence of scaling in random networks. *science*, 286(5439):509–512.

Barrett, C. B., Reardon, T., Swinnen, J., and Zilberman, D. (2022). Agri-food value chain revolutions in low-and middle-income countries. *Journal of Economic Literature*, 60(4):1316–1377.

Beckman, J. and Countryman, A. M. (2021). The importance of agriculture in the economy: impacts from covid-19. *American journal of agricultural economics*, 103(5):1595–1611.

Brandwatch (2020). How eating & drinking habits have changed.

Bureau of Economic Analysis (2023a). Gross Output by Industry - Detail Level. Underlying Detail Tables, Annual, 2017–2022. https://www.bea.gov/itable/gdp-by-industry, accessed: 2024-04-25.

Bureau of Economic Analysis (2023b). The Use Table (Supply-Use Framework), 2017. https://apps.bea.gov/iTable/?isuri=1&reqid=151&step=1, accessed: 2024-04-25.

Cardoza, M., Grigoli, F., Pierri, N., Ruane, C., et al. (2020). Worker mobility and domestic production networks. Technical report, International Monetary Fund.

Dalheimer, B., Bellemare, M. F., and Lim, S. (2023). Global agricultural value chains and food prices. Working Paper.

Dries, L. and Swinnen, J. F. (2004). Foreign direct investment, vertical integration, and local suppliers: Evidence from the polish dairy sector. *World development*, 32(9):1525–1544.

Engemann, H. and Jafari, Y. (2022). Covid-19 and changes in global agri-food trade. *Q Open*, 2(1):qoac013.

FactSet (2021). Supply Chain Relationships - Data and Methodology Guide. https://www.factset.com/marketplace/catalog/product/factset-supply-chain-relationships, documentation accessed on 2023-02-06.

FactSet (2023). FactSet Supply Chain Relationships [Dataset]. https://www.factset.com/marketplace/catalog/product/factset-supply-chain-relationships, data accessed from server on: 2024-03-20.

Ferguson, S. and Ubilava, D. (2022). Global commodity market disruption and the fallout. *Australian Journal of Agricultural and Resource Economics*, 66(4):737–752.

FoodNavigator (2020). Is coronavirus changing how we eat.

Gabaix, X. (2011). The granular origins of aggregate fluctuations. *Econometrica*, 79(3):733–772.

Garicano, L., Rohner, D., and di Mauro, B. W. (2022). *Global economic consequences of the war in Ukraine: Sanctions, supply chains and sustainability*. CEPR Press.

Gereffi, G., Humphrey, J., and Sturgeon, T. (2005). The governance of global value chains. *Review of International Political Economy*, 12(1):78–104.

Giovannetti, G. and Marvasi, E. (2016). Food exporters in global value chains: Evidence from italy. *Food Policy*, 59:110–125.

Gofman, M. and Wu, Y. (2022). Trade credit and profitability in production networks. *Journal of Financial Economics*, 143(1):593–618.

Guo, H., Liu, Y., Shi, X., and Chen, K. Z. (2021). The role of e-commerce in the urban food system under covid-19: Lessons from china. *China Agricultural Economic Review*, 13(2):436–455.

Guo, J., Jin, S., Zhao, J., and Li, Y. (2023). E-commerce and supply chain resilience during covid-19: Evidence from agricultural input e-stores in china. *Journal of Agricultural Economics*, 74(2):369–393.

Guo, J., Jin, S., Zhao, J., Wang, H., and Zhao, F. (2022). Has covid-19 accelerated the e-commerce of agricultural products? evidence from sales data of e-stores in china. *Food Policy*, 112:102377.

Huang, Y., Lin, C., Liu, S., and Tang, H. (2023). Trade networks and firm value: Evidence from the us-china trade war. *Journal of International Economics*, page 103811.

Huneeus, F. (2018). Production network dynamics and the propagation of shocks. Working Paper.

Kerr, W. A. (2020). The covid-19 pandemic and agriculture: Short-and long-run implications for international trade relations. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 68(2):225–229.

Lebastard, L. and Serafini, R. (2023). Understanding the impact of covid-19 supply disruptions on exporters in global value chains. *The Centre of Economic Policy Research (CEPR). VoxEU Column*.

Lim, S. (2021). Global agricultural value chains and structural transformation. Technical report, National Bureau of Economic Research.

Lim, S. and Kim, S. W. (2022). Global agricultural value chains and employment growth. *Journal of the Agricultural and Applied Economics Association*, 1(4):402–418.

Litton, M. M. and Beavers, A. W. (2021). The relationship between food security status and fruit and vegetable intake during the covid-19 pandemic. *Nutrients*, 13(3):712.

Martin, J., Mejean, I., and Parenti, M. (2020). Relationship stickiness, international trade, and economic uncertainty. Discussion Paper 15609, CEPR.

Michelson, H. C. (2017). Influence of neighbor experience and exit on small farmer market participation. *American Journal of Agricultural Economics*, 99(4):952–970.

Montalbano, P., Nenci, S., et al. (2020). The effects of global value chain (gvc) participation on the economic growth of the agricultural and food sectors.

Oberfield, E. (2018). A theory of input–output architecture. *Econometrica*, 86(2):559–589.

Pahl, S., Brandi, C., Schwab, J., and Stender, F. (2022). Cling together, swing together: The contagious effects of covid-19 on developing countries through global value chains. *The World Economy*, 45(2):539–560.

Punthakey, J. (2020). Foreign direct investment and trade in agro-food global value chains. *OECD Food, Agriculture and Fisheries Papers*, (142).

Sargent, T. J. and Stachurski, J. (2024). *Economic networks: Theory and computation*, volume 53. Cambridge University Press.

Scoppola, M. et al. (2022). Agriculture, food and global value chains: issues, methods and challenges. *Bio-based and Applied Economics*, 11:91–92.

Seetharaman, P. (2020). Business models shifts: Impact of covid-19. *International Journal of Information Management*, 54:102173.

Singh, S., Kumar, R., Panchal, R., and Tiwari, M. K. (2021). Impact of covid-19 on logistics systems and disruptions in food supply chain. *International journal of production research*, 59(7):1993–2008.

Stevens, A. W. and Teal, J. (2024). Diversification and resilience of firms in the agrifood supply chain. *American Journal of Agricultural Economics*, 106(2):739–778.

Supermarket News (2020). Asian consumers are rethinking how they eat post-covid-19.

World Trade Organization (2023). World trade report 2023.

WorldBank (2020). *World Development Report 2020*. Number 32437 in World Bank Publications - Books. The World Bank Group.

A Appendix Tables and Figures

Table A.3: List of Variables

Variables	Description	% missing		
Link-level variables				
Reporting firm ID			0	
Partner firm ID			0	
Link type	Customer, supplier		0	
Start date			0	
End date			0	
Ownership ties				
Firm ID			0	
Parent ID	= Firm ID if self-owned		0	
Ultimate parent ID	= Firm ID if self-owned		0	
Start date			0	
End date			0	
Firm-level variables		agribus.	act. covered agribus.	partners
Entity name		0	0	0
Primary industry	NAICS 6-digit (2022 vintage)	0	0	10.82%
Country	Country of incorporation	0	0	0.02%
Type	e.g. public, private, subsidiary	0	0	0.03%
Sales	Annual sales in 2020 USD	61.85%	9.90%	-

Note: This table details the variables obtained from FactSet. The last columns show the percentage of firms with missing industry, country or type information. For sales, the percentage of year-firm cells with missing sales information for the years 2014-2021 is shown. The share of missing cells is detailed separately for all 17,527 agribusinesses in the dataset, the 4645 actively covered agribusinesses (i.e. firms that appear as reporting firm in a given year), and all 37,000 partner firms. Note that partner firms can be agribusinesses.

Table A.4: List of Agri-business NAICS Codes

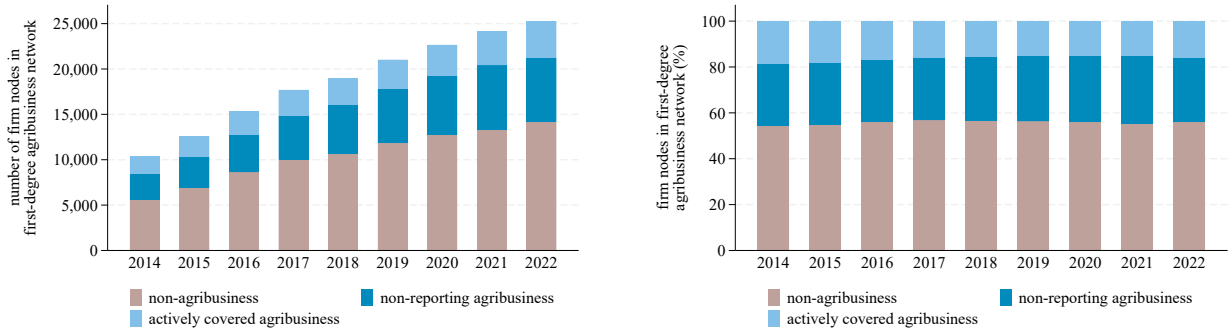
Description	**NAICS**
Agriculture	11XXXX
Food Manufacturing	311XXX
Beverage and Tobacco Manufacturing	312XXX
Fertilizer, Pesticide, and Other Agricultural Chemical Manufacturing	3253XX
Pharmaceutical and Medicine Manufacturing	3254XX
Agricultural Implement Machinery Manufacturing	33311X
Grocery and Related Product Merchant Wholesalers	4244XX
Farm Product Raw Material Merchant Wholesalers	4245XX
Beer, Wine, and Distilled Alcoholic Beverage Merchant Wholesalers	4248XX
Nursery, Garden Center, and Farm Supply Stores	444220
Food and Beverage Stores	445XXX
Pharmacies and Drug Stores	45611X
General Merchandise Stores (Department Stores, Warehouse Clubs, Supercenters)	455XXX
Florists	4593XX
Food Services and Drinking Places	722XXX

Note: This table details the NAICS 6-digit codes used to select our sample of agribusiness companies. An "X" is used as a placeholder for all narrow 6-digit industries within a broader 2, 3, 4, or 5 digit sector. We defined the industry broadly given the fact that pharmaceutical companies source many of their ingredients from the agricultural sector, the growing size of the nutraceutical market, and the role of drug stores and general merchandise stores as retailers of processed food.

Table A.5: US Fortune 500 Agri-Business Companies (March 2022)

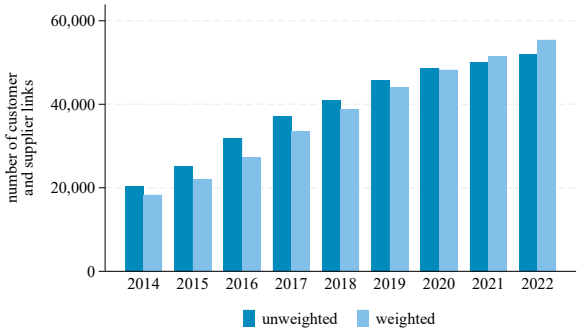
Name	NAICS
AGCO Corp	Farm Machinery and Equipment Manufacturing
Albertsons Cos Inc	Supermarkets and Other Grocery Retailers
Altria Group Inc	Tobacco Manufacturing
Andersons Inc	Farm Management Services
Archer Daniels Midland Co	Farm Management Services
CHS Inc	Farm Management Services
Campbell Soup Co	All Other Miscellaneous Food Manufacturing
Chipotle Mexican Grill Inc	Limited-Service Restaurants
Coca Cola Co	Soft Drink Manufacturing
Conagra Brands Inc	Frozen Specialty Food Manufacturing
Constellation Brands Inc	Breweries
Corteva Inc	Pesticide and Other Agricultural Chemical Manufacturing
Costco Wholesale Corp	Warehouse Clubs and Supercenters
Deere & Co	Farm Machinery and Equipment Manufacturing
General Mills Inc	All Other Miscellaneous Food Manufacturing
Hershey Co	Chocolate and Confectionery Manufacturing from Cacao Beans
Hormel Foods Corp	Animal (except Poultry) Slaughtering
Ingredion Inc	Flavoring Syrup and Concentrate Manufacturing
Kellanova	Other Snack Food Manufacturing
Keurig Dr Pepper Inc	Soft Drink Manufacturing
Kraft Heinz Co	All Other Miscellaneous Food Manufacturing
Kroger Co	Supermarkets and Other Grocery Retailers
McDonalds Corp	Limited-Service Restaurants
Merck & Co Inc	Pharmaceutical Preparation Manufacturing
Molson Coors Beverage Co	Breweries
Mondelez International Inc	Cookie and Cracker Manufacturing
Mosaic Co	Phosphatic Fertilizer Manufacturing
Pepsico Inc	Soft Drink Manufacturing
Performance Food Group Co	Food Service Contractors
Philip Morris International Inc	Tobacco Manufacturing
Publix Super Markets Inc	Supermarkets and Other Grocery Retailers
Rite Aid Corp	Pharmacies and Drug Retailers
Smucker Jm Co	Dog and Cat Food Manufacturing
Starbucks Corp	Snack and Nonalcoholic Beverage Bars
Target Corp	Warehouse Clubs and Supercenters
Tractor Supply Co	Outdoor Power Equipment Retailers
Tyson Foods Inc	Animal (except Poultry) Slaughtering
US Foods Holding Corp	General Line Grocery Merchant Wholesalers
United Natural Foods Inc	General Line Grocery Merchant Wholesalers
Walgreens Boots Alliance Inc	Pharmaceutical Preparation Manufacturing
Walmart Inc	Warehouse Clubs and Supercenters
Yum Brands Inc	Limited-Service Restaurants
Zoetis Inc	Pharmaceutical Preparation Manufacturing

Figure A.9: Number of Firm Nodes in the Network over Time



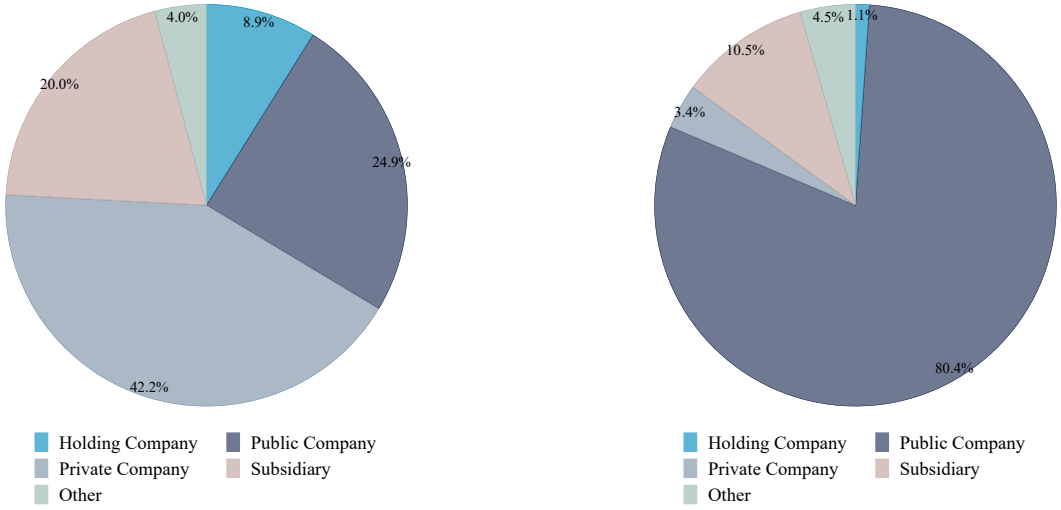
Note: The graphs shows the number of nodes observed in the agribusiness supply chain network sample over time. Slightly more than half of the nodes are non-agribusiness entities that have a direct customer or supplier link to one of the agribusinesses in our sample. Actively covered agribusiness entities account for 15% to 18% of the nodes in a given year. Overall, the number of nodes is increasing over time, with the share of non-agribusiness entities and agribusiness entities remaining relatively stable.

Figure A.10: Number of Supply Chain Links over Time



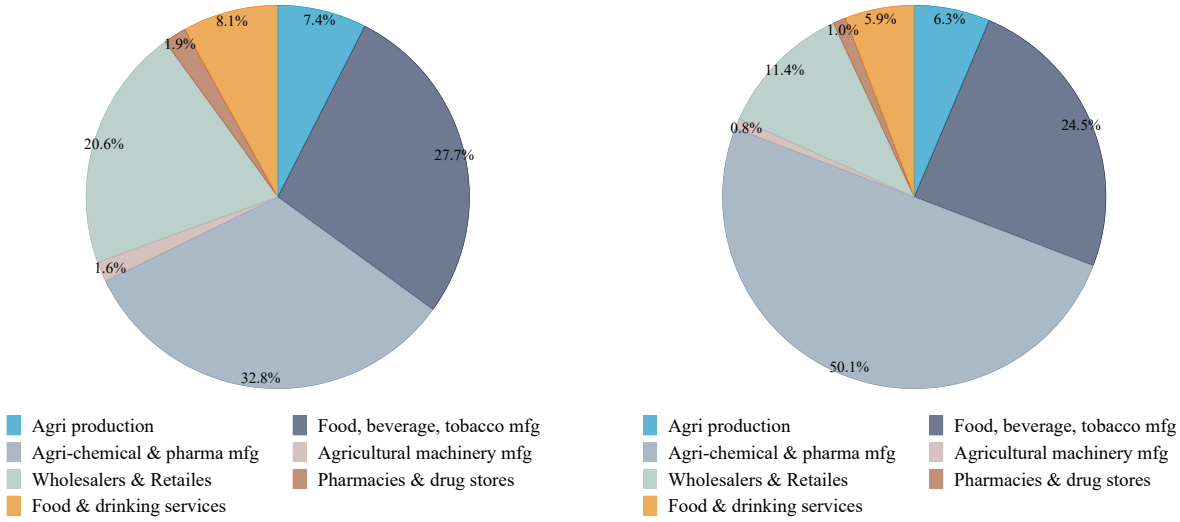
Note: The graphs shows the number of customer and supplier links formed by the agribusiness companies in our sample over time. Links are formed either between two agribusinesses or between an agribusiness and a non-agribusiness company. The unweighted link count reflects a dummy which equals one whenever a supply chain link exists between two companies in a given year. The weighted link statistic accounts for the share of the year that a given link is active and is scaled in case two entities form multiple relationships.

Figure A.11: Entity Type of Agribusiness Companies in the Sample



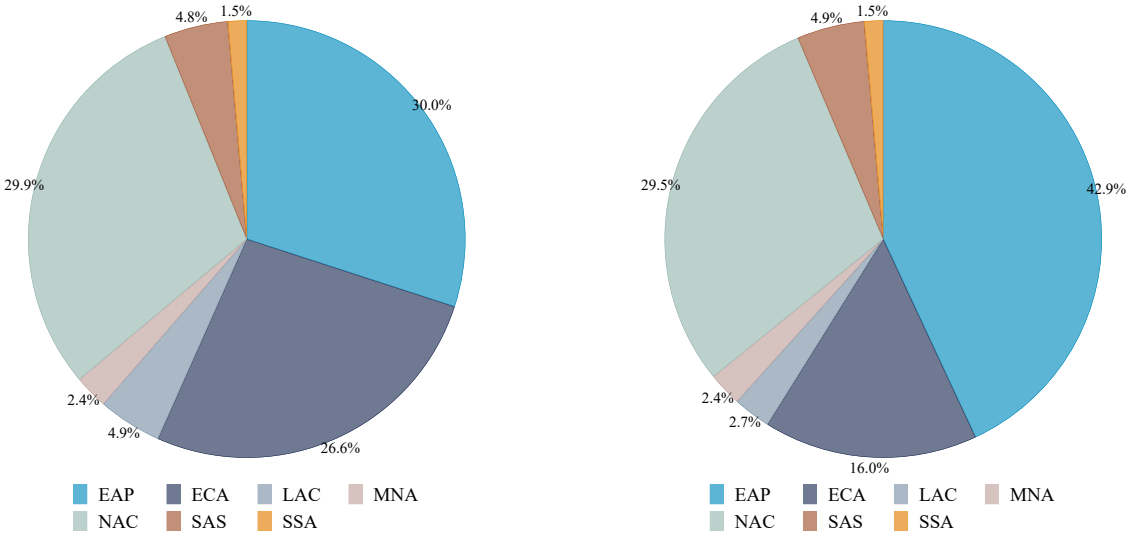
Note: The graph details the entity type of the agribusinesses observed in the sample. The left panel includes all agribusiness firms in the sample, while the right panel is limited to actively covered companies. The majority of agribusinesses are private companies, followed by public companies, subsidiaries, and holding companies. Public companies dominate the subset of actively covered firms, where relatively fewer private companies are observed. Other entity types include joint ventures, non-profit organizations, government entities, foundations, operating divisions or corporate assets, and entities that are extinct as of March 2024.

Figure A.12: Industry Affiliation of Agribusiness Companies in the Sample



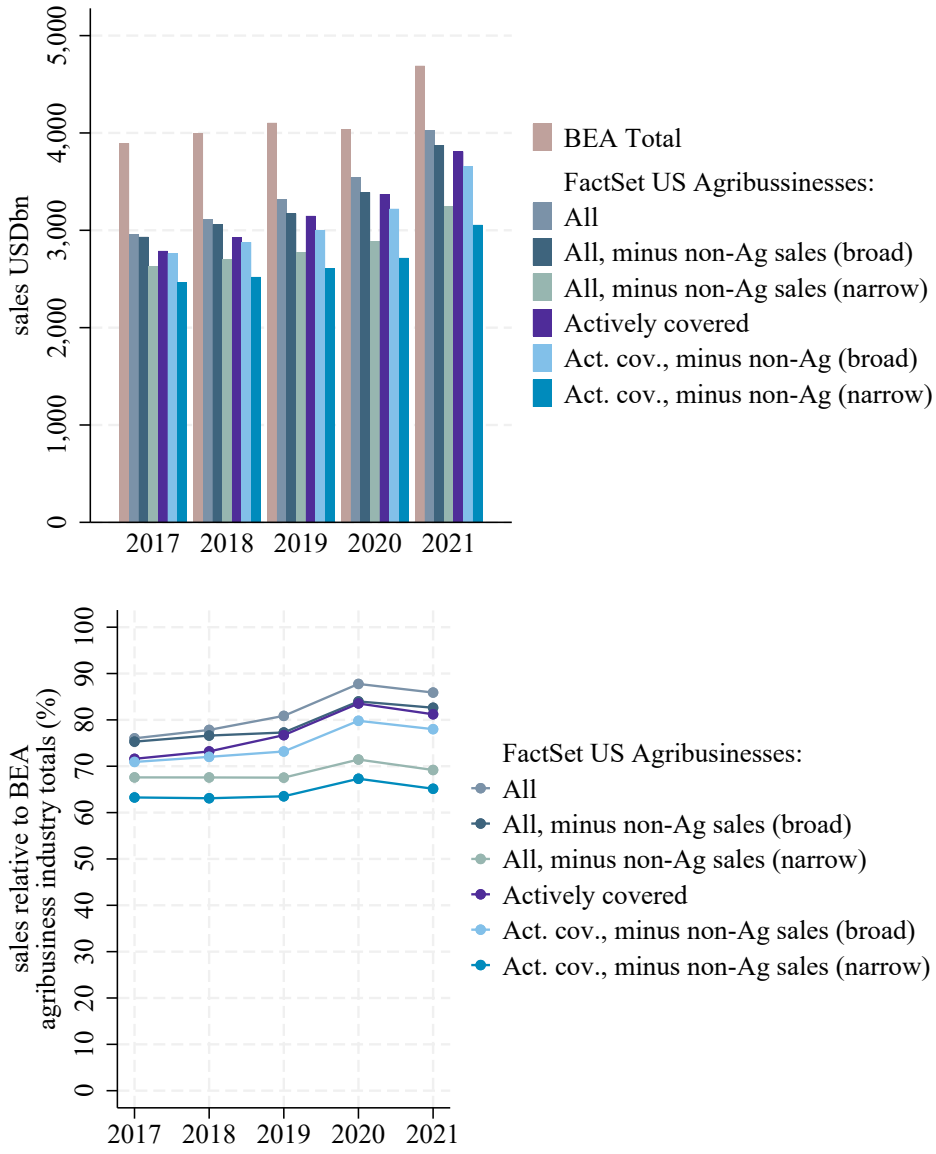
Note: This graph displays the industry affiliation of agribusiness firms in our sample, categorized by broader sectors. The left panel includes all agribusiness firms in the sample, while the right panel is limited to actively covered companies.

Figure A.13: Region of Domicile of Agribusiness Companies in the Sample



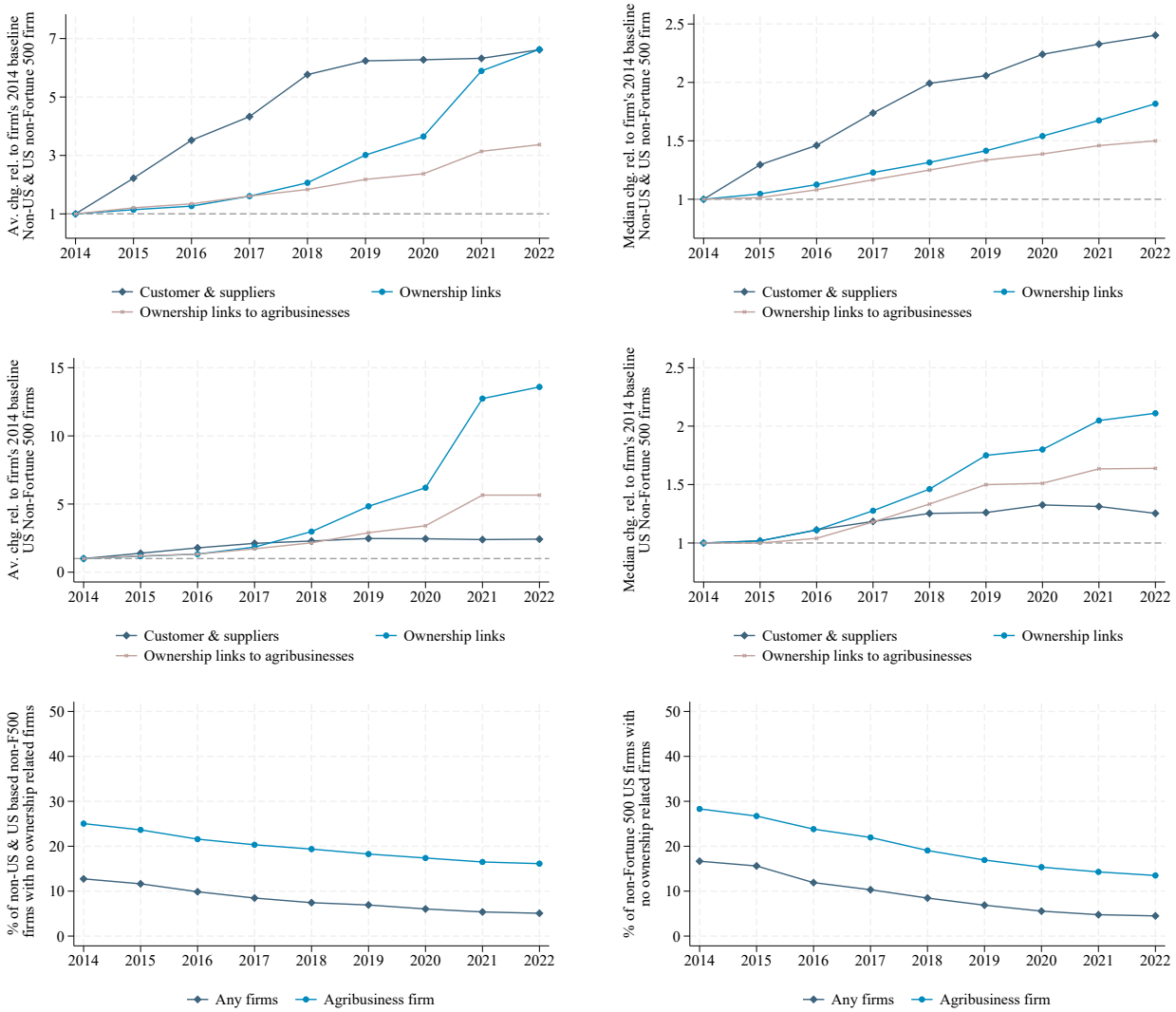
Note: This graph displays the region of domicile of agribusiness firms in our sample. The left panel includes all agribusiness firms in the sample, while the right panel is limited to actively covered companies. The geographical classifications in this study follow the World Bank Geographic Regions, which encompass the following regions: EAP (East Asia and Pacific), ECA (Europe and Central Asia), LAC (Latin America and Caribbean), MNA (Middle East and North Africa), NAC (North America), SAS (South Asia), and SSA (Sub-Saharan Africa).

Figure A.14: Sample Coverage in Terms of Sales Relative to US Industry Totals



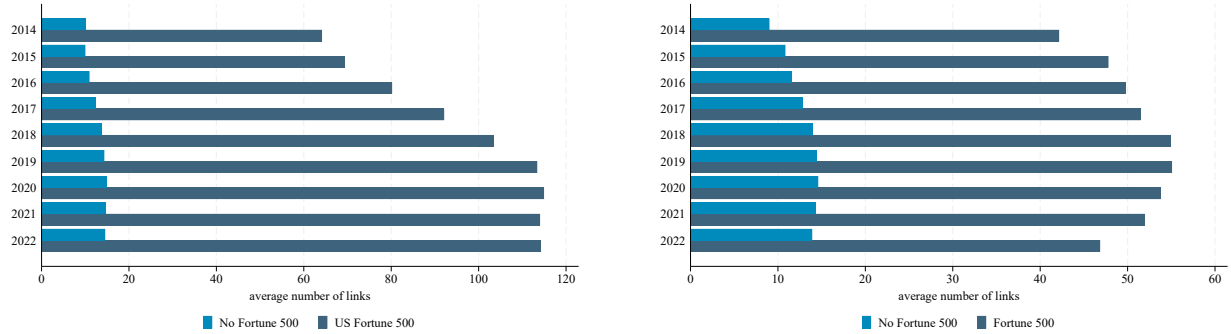
Note: The two graphs benchmark the sales of US agribusinesses in our sample against total US agribusiness industry output. The upper graph shows total sales, the lower graph details the share relative to BEA total industry output. Sales data for the sample US agribusinesses in FactSet with non-missing or negative sales is aggregated across all agribusinesses, and across the subset of actively covered firms. Some series deduct sales reported for non-agribusiness business segments, distinguishing between a "narrow" and "broad" approach to identify relevant revenue statistics.

Figure A.15: External Links vs. Ownership Integration



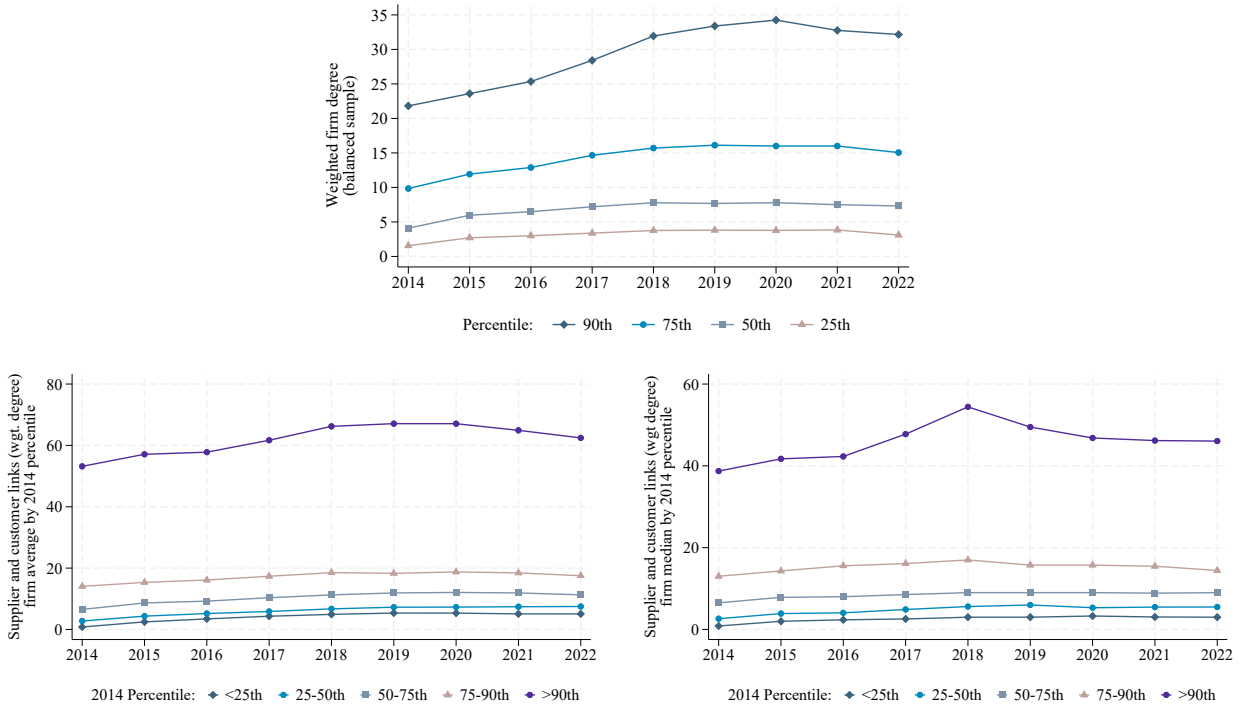
Note: This graph compares the evolution of a firm's number of customers and suppliers to the number of firms that it is linked to via ownership ties (either parent, subsidiary, or common parent). For each firm, the change in the number of externally and internally connected firms is computed relative to its 2014 value. The upper panel shows the yearly average (left) and median (right) for the sample of actively covered non-US-based firms and non-Fortune 500 US firms. The middle panel shows the equivalent statistics for US-based non-Fortune 500 US firms. Relative to the baseline graphs presented in Figure 2 and Figure 3, only constantly observed actively covered companies with a non-zero number of links across both ownership link categories (ownership-related entities, and ownership-related agribusinesses) in 2014 are included. By construction, customer & supplier linkages are always non-zero in 2014 for the balanced firm sample. The bottom left panel shows the share of constantly observed actively covered non-US based and non-Fortune-500 US companies with no ownership ties or no agribusiness within their corporate family in a given year. The right graph shows the shares for the subset of US non-Fortune 500 companies.

Figure A.16: Centrality of Fortune 500 Agribusiness Companies



Note: The graph shows the average number of customer and supplier links ("degree centrality") for actively covered US Fortune 500 agribusiness companies and non-US based firms or non-Fortune 500 US-based firms over time. Fortune 500 agribusinesses are identified from the March 2022 list of US Fortune 500 companies. The left graph depicts the degree centrality of actively covered enterprises based on their links to all firms observed in the network in a given year, the right graph depicts the degree centrality of actively covered enterprises while including only links between firms that are constantly observed in the sample (that is excluding any entrants or exiters between 2014 and 2024).

Figure A.17: Distribution of Firm Links and Evolution of Firm Links in the Balanced Sample of Firm Nodes



Note: The upper graph depicts the 25th, 50th, 75th, and 90th percentile of the average number of supplier and customer links per firm in a given year. It shows the number of links to constantly observed partner firms for actively covered agribusiness firms that have at least one link to a constantly observed partner firm every year. The bottom graphs track the evolution of links based on firms' 2014 percentile, including again a balanced set of agribusiness and partner firms. The left graph shows the average number of links, and the right graph shows the median number of links.