



From Big Ag to Big Finance: a market network approach to power in agriculture

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Abstract

Critics charge that agriculture has reached an unsustainable level of consolidation and expropriation, as exemplified by the supply-chain breakdown of the COVID-19 pandemic. Simultaneously, advocates suggest the current system serves consumers well by keeping prices low and access to choices high. At the center of this debate rests a disagreement over how to compute market power to identify monopolies and oligopolies. We propose a method to study power across different sectors by using Social Network Analysis (SNA) to analyze key players, the presence of core-periphery structures, and agricultural consolidation. We test our market network approach to power through an analysis of the top ten pork powerhouses. We find that Big Finance is closely tied to Big Ag, and that key players limit the capacity for more peripheral actors, like growers, equipment producers, and regional banks, to engage in the network. We identify system level risk of collapse and suggest pathways for reform.

Keywords Corporate agriculture · Financialization · Hog production · Market power · Monopolies · Oligopolies · Social network analysis

Introduction

Ongoing concentration in agriculture receives two starkly different receptions. Some celebrate mergers and acquisitions as achieving intra-organizational efficiency with consumers as “the big winners” (Crespi et al. 2012, p. 691). Advocates of consolidation argue that concentration does not negatively impact prices (MacDonald 2016) and even go so far as to say concentrated markets in agriculture produce more competitive pricing (Sexton 2013). They do so

by computing market power, which measures a single firm’s contribution, like Smithfield Foods, relative to the total output of a specific market, like pork meat packing. Firms can hypothetically practice market power in a variety of ways, for example lowering what they pay input providers, increasing costs for consumers, reducing the quality of the product they produce or the ease or price at which farmers can buy or sell. Even though firms may play an outsized role as a buyer or seller, thus acting as the main monopolistic player or amongst a handful of oligopoly players, advocates counter that these firms are fundamentally efficient because they reduce transaction costs and keep consumer prices low (U.S. GAO 2009; Sexton and Xia 2018). These approaches, with a sprinkling of other contract-centric considerations, remain the prevailing ones for U.S. antitrust laws intended to remedy anticompetitive behavior (Moss 2016).

Critics, however, posit that this prevailing market power approach leaves out those hurt most directly by consolidation: workers, farmers, and rural communities (Hendrickson et al. 2020; Garcés 2020). Further, they suggest that such commodity or product specific approaches to market power overlook intersectoral dependencies that lead to supply chain failures alongside human and animal suffering, exemplified by the fallout of COVID-19 hotspots at industrial

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meat processing facilities (Hendrickson 2020; Carrillo and Ipsen 2021). Reduced transaction costs are a matter of legal rights afforded to the largest corporate conglomerates, leaving them the beneficiaries of the efficiency argument by design (Paul 2022). For fair competition, coordination rights between firms should belong to “dispersed, horizontal, and democratic forms” rather than the most “concentrated, vertical, [and] hierarchical” (Paul 2022). Likeminded scholars also warn that financial investment and corporate structure make sector-specific understandings of monopoly and oligopoly power somewhat arbitrary and insensitive to the systemic risks created by consolidation—for example treating hogs as separate from beef or processing as separate from retail (Moss 2016; Clapp 2014; Foer 2016; Domina and Taylor 2010; Cartensen 2008). These critics also warn that prevailing anti-trust policy responds to proposed mergers, but often does not address the conditions that enable unequal power relations in the first place (Hendrickson et al. 2019).

We propose a methodology to more systematically study power in agriculture and more specifically market power. Our methodology does so through (1) key player analysis, where power is quantified via a firm’s financial ties to other entities; (2) core and periphery positions, where elite firms become dependent on one another and limit broader access to the network; and lastly (3) testing distribution patterns in the network to determine the level of consolidation. This three-pronged approach—key player analysis, core-periphery structures, and distribution—suggest an alternative approach to studying power in agriculture. Taken together, we analyze market *network* power.

We tested our market network approach to power on the pork powerhouses, as hog production is a rapidly consolidating agribusiness sector of public concern (MacDonald 2016; Wise and Trist 2010). We created a dataset from LexisNexis SmartLinx Comprehensive Business Reports related to the top ten pork powerhouse companies to capture relationships relative to corporate structure and financial capital, what we understand as corporate finance. This dataset included 559 firms exhibiting 720 financial ties. Our analysis found the network to be highly consolidated. In addition to identifying core and periphery structures shaping network access and power, our analysis also uncovered that out of all firms, financial firms are key to the network. The publicly funded Farm Credit System (FCS)—largely overlooked in current studies of financialization as it acts under House and Senate committee oversight—is the most prevalent financial firm in the network. Pinpointing these financial conglomerates in the network helps explain the origins of capital that enables monopolies and oligopolies in the first place, in addition to merger focused anti-trust regulation.

We begin our paper by considering how a Social Network Analysis (SNA) fits into existing approaches to power, and more specifically market power, in agriculture (Friedmann

and McMichael 1989; Mooney 1986, 1988; Green 1987; Burch and Lawrence 2009; Ouma 2016; Christophers 2018). We build on this literature to propose our methodology, which recasts market power around relationships—what interacts and makes money off what, those left on the periphery, and those left out altogether.

Power in agriculture

Relations and networks

A network analysis of power in agriculture switches emphasis from power via firms’ relative contribution to the total output in a sector or commodity specific market to power via financial relationships across firms. The concept of power from a network perspective is typically derived from how embedded a node is in the network rather than on some sort of atomistic attribute. For instance, Granovetter (1973) famously found that landing a job had more to do with job seekers’ exploitation of weak ties than common individual characteristics (i.e., it’s not *what* you know, it’s *who* you know). Howard (2021), drawing on Nitzan and Bichler (2009), called for centering agriculture’s political economy on such network-based relationships, rather than only production.

Network analysis moves away from more conventional approaches to markets, where firms are assumed to be discrete entities that only operate within a particular farm market. Conventional and prevailing methods to study monopoly and oligopoly (seller) or monopsony and oligopsony (buyer) power center around a specific firm producing a specific output within a specific market. Two market power measures—CR4 (four firm concentration ratio) and HHI (Herfindahl–Hirschman Index)—rely on public data to compare any given firm’s power within a given market, defined by industry-specific codes. The CR4 concentration ratio is the sum of the market share of the four largest companies in an industry and the HHI is the sum of the squared shares for all sellers in the designated industry (James et al. 2012). To designate an industry, scholars and practitioners use the North American Industry Classification System (NAICS) six-digit codes (Crespi et al. 2012). These NAICS classifications can be so slight in their differences that they miss the overall entanglements of any one international and multi-layered subsidiary corporation. For example, NAICS codes separate animal (except poultry) slaughtering from meat processed from carcasses; and creamery butter manufacturing is considered distinct from cheese manufacturing. Likewise, computation of market power for meat packers that produce processed meat products is distinct from their many other subsidiaries or holdings in other sectors. Further, it can be difficult to have an accurate record of sales for any one

firm or the total sales in an industry because of corporate structure and limited public disclosures for firms. Wise and Trist (2010) warn in their study of hog buyer power, that “obtaining all the information necessary to calculate this [HHI] measure is one of the greatest challenges to its use, because many of these firms are privately held and market information is not readily available” (p. 5). More generally, Sexton and Xia (2018, p. 244) write there is a “paucity of appropriate data” to compute market power in agriculture. Despite the limitations of narrow industrial classifications for firm power and uncertain data, HHI and CR4 remain the prevailing measures of market power for anti-trust and anti-monopoly enforcement in the U.S. and the European Commission (Wise and Trist 2010; Sexton and Xia 2018).

Network approaches, in contrast, offer a means to capture the multiple financial relationships between firms operating in what are traditionally conceived of as distinct markets. Focusing on single product or industry to measure power misses the network level diversification utilized by firms into other sectors to outperform their competitors (Howard 2021). On a more aggregate level, these narrow market sector analyses miss the systematic entanglements that typify finance and production today (Omarova 2013). Firms seek not just profit (Krippner 2011) or even monopoly profit (Christophers 2018), but advantage relative to other key players in the network. For example, the retailer Walmart created its own private equity company to invest in supplier diversity. Likewise, Cargill uses Black River Asset Management to trade in equities and commodities while investing in energy worldwide (Burch and Lawrence 2009; Salerno 2017). Analyzing power—monopoly, oligopoly or otherwise—requires a method more attuned to the web of relations that create concentrated power and systemic risk.

Finance and corporate structure

Intersectoral relationships that defy industry boundaries in agriculture can be attributed as process to financialization, as structure to corporations, and as means to finance capital. Harvey (2003) identifies finance capital in two parts: (1) traditional credit flows to finance productive activities; and more recently (2) the use of finance to simply make money through speculation on commodity futures, currency values, debt, and other securities. Foster (2007) uses similar language, arguing that financialization is necessary for what he calls, “monopoly-finance capital,” where capitalists become dependent on finance to create money capital, and in doing drive speculative bubbles (Foster 2007, p. 6). In agriculture, Ouma (2016) stresses that more attention must be paid to the way agri-finance capital is formed, not just financialization as inevitable process.

Unpacking those black boxes or formations of finance is crucial (MacKenzie 2005), especially to tackle unfair and

anticompetitive practices. Publicly traded, multi-layered subsidiary corporations utilize a web of dozens and even hundreds of subsidiaries to move capital between entities, reduce tax obligations, and reduce firm-level culpability for the riskiest operational components (Prechel and Morris 2010). Likewise, private industrial animal conglomerates typically use Limited Liability Companies (LLCs) as their go-to organizational form to reduce public accountability, tax liability, and responsibility for environmental wrongdoing (Ashwood et al. 2014). The relationships that hold these organizational forms together cross what can initially appear to be unrelated sectors (Ashwood et al. 2022). As a consequence, these types of relationships remain overlooked in studies of market power. New, unfolding vehicles of financial investment like commodity index funds, real estate investment trusts, mutual funds, and equity-related funds like exchange traded funds further underscore the extent of cross sectoral investment and ownership in agriculture today (Clapp 2019).

Corporate finance has, in short, disintegrated the traditional boundaries of farm product markets. Incorporating the material means of financial capital but also bringing structure to bear, we use the term corporate finance to capture the obfuscated structure of corporations and their use of financial capital to keep ultimate beneficiaries uncertain through private firms and securities. Our analysis of corporate finance—flows simultaneous to structure—helps elucidate what is made to be invisible to avoid culpability for monopolistic or oligopolistic practices. Doing so requires tracing ownership and financial relationships between firms.

Using network analysis to capture trends amongst untransparent forms of corporate finance helps researchers elucidate the “obscured” (Omarova 2013, p. 293) understanding of the extent to which corporations and financial institutions engage with commodity production. In other words, it offers a means to understand what Vitali et al. (2011) call the architecture of ownership. In their SNA, Vitali et al. (2011) identified the main owners of transnational corporations globally by analyzing a variety of ownership forms, such as member share owners. Using a sample of 43,060 companies in an Organisation for Economic Co-operation and Development (OECD) dataset, Vitali et al. (2011) identified the most powerful financial owners globally, which includes entities we also find active in the hog sector: Citigroup and Bank of America. Vitali et al. (2011) describe these financial entities as “top holders within the core” that operate as “an economic ‘super-entity’ in the global network of corporations” (p. 36). Omarova (2013) suggests such commercial firms’ more prevalent role in finance comes from their recent allowance by the Securities and Exchange Commission to operate deposit taking institutions—namely to act somewhat like banks. This suggests, as does the financialization of agriculture literature more

generally (Ouma 2016), that researchers and policy makers need measures of industrial or productive power that focus on financial relationships, regardless of the sector (Prechel 2021; Harris 1976).

Bringing banking relationships into the study of power in food production helps researchers consider the unfolding alliances between industry and capital, while also being cognizant of the long-standing role of finance in agriculture. Farm debt is a crucial form of relational power and has been for over a century since banking took on a key role in promoting mechanization and intensification through loans (Mooney 1988; Jones and Durand 1954). Through the 1916 Federal Farm Loan Act, the government created the basis for the Farm Credit System, the first government-sponsored enterprise in U.S. history (Hutchins 2022). The 1923 Agricultural Credits Act established a loan system for land (Larzelere and Law 1943; Clarke 1981). Like more current forms of financial investment and corporate structures, associated banks used holding company structures to receive tax-exempt status to provide loans to farmers. This special privilege was affirmed by the US Supreme Court when it upheld the constitutionality of the Farm Loan Act (Manner 2014; Larzelere and Law 1943). With the arrival of the Great Depression, farmers could not pay their loans, and facing dispossession, there was “partial cause for evidence of violence and of revolutionary spirit among farmers” (Larzelere and Law 1943, p. 11). The government responded in 1933 by expanding access to credit and support through Federal Land Banks; Federal Intermediate Credit Banks; the Bank for Cooperatives; and the Production Credit Corporation and Production Credit Associations (Larzelere and Law 1943). As Mooney (1986) writes, those who received lines of credit gained relational access to banks and eventually displaced those who did not. Finance operated as a key agent driving the political economy of agriculture. Later, for example, the Farm Credit System took an active role in promoting the construction of more intensive hog confinements after the 1998 crash of the hog market, when prices hit their lowest level since 1964 (Schrader 1998; Curry Raper et al. 2006; Hanson 2020).

Today, the Farm Credit System (FCS) plays arguably an even more powerful role in agriculture. In the 1960s, about 60% of farm lenders were individuals or “others” (Monke 2018). Now, commercial banks hold 42% of farm debt, and the FCS holds another 41%, versus FCS’s less than 20% in the 1960s (Monke 2018). The system has changed markedly since its initial inception. Today, FCS has only 69 associations of borrowers, whereas it had over 1000 in the 1970s. The remaining associations fall within four general banks: AgFirst (southeast up to Pennsylvania); AgriBank (Midwest and upper south); CoBank (the west and northwest); and Farm Credit Bank of Texas (Texas and neighboring New Mexico) (Farm Credit 2022). These associations receive

capital from debt securities sales on Wall Street, handled by the Farm Credit Banks Funding Corporation (Moss and Gunderson 2013). US and global investors who purchase these debt securities have their principal and interest payments insured by the Farm Credit System Insurance Corporation, a government-controlled corporation subject to available funds (Farm Credit Insurance Corporation 2022). Investors receive the privileged status of tax-free capital gains and real estate portfolio provisions (Tapp 2020; Monke 2018; Christophers 2018). Customer members of regional FCS associations can use the net income they receive to build their institution’s financial portfolios or pass on their income through patronage dividends (Monke 2018; Farm Credit 2022). SNA offers a means to identify the current role of these FCS associations as well as other banks and related financial entities.

Core and periphery relationships

Power, while in part about the existence and accumulation of relations, is also about the way firms position themselves to practice control and domination through leveraging. James et al. (2012) call for researchers to analyze dependency between nodes within a network. They frame dependency as the opposite of democracy, where the former means the unwelcome imposition of power, and the latter means open circulation of power where no one actor dominates. They call for, “a better conceptual model that helps to explain the existence and exercise of power within the agrifood system” (James et al. 2012, p. 7), and propose network exchange theory (NET) as a potential solution. NET theory, rather than assuming ‘rational’ decision making, instead begins with the presumption that actors behave in accordance with power imbalances and leverage them to their benefit (James et al. 2012). In contrast, they write, agricultural economists largely continue to assume firms act independently to maximize their utility or profit in any single farm market. This firm-centric, rather than systems level thinking, is increasingly antiquated in light of effusive investment and intersectoral relationships. In contrast, James et al. (2012) call for researchers to analyze positions (core or periphery) and the type of network connection.

SNA is particularly suited to answering this call by looking at key firms that bottleneck, i.e. companies that prevent other actors from accessing the broader network. This constrains the choices those in the network can make or whether others can enter the network at all (Stuart 2009; Stuart and Schewe 2016). Likewise, SNA can reveal nodes that have constitutive ties, i.e. where actors depend on each other for key resources. Those actors then are at risk in the event the other fails to deliver, particularly during a crisis like a pandemic. To capture these dynamics, we analyze market network power by identifying key power holders, those

on the periphery, dependency between key players, and the potential of those with power to dominate even more. While constitutive ties suggest some sort of reciprocity, when limited to a few privileged actors, these ties create system level vulnerability, as we discuss later in the paper.

Methods and research questions

We use SNA informed by studies of corporate organization to measure power in agriculture (Prechel and Zheng 2012; Ashwood et al. 2022). Remaining cognizant of corporate organization and novel forms of investment, we use SNA as a tool to evaluate social relationships by applying networks and graph theory to business operating structure (Scott and Carrington 2011). SNA need not be limited only to financial ties, as a social network refers to a system of relationships between actors or nodes, such as individuals, regions, or any variety of entities (Bandyopadhyay et al. 2011). However, we focus in this paper on relationships we can identify through business reports. What's useful for the study of power in agriculture is SNA's set of procedures for "analysing the presence, direction and strength of the lines which connect these points" (Scott 1988, p. 113). SNA provides a means to identify key players, core and periphery structures, and consolidation via distribution amidst a complex web of corporate relationships and financing.

We identify corporate finance by analyzing relationships between firms, which we identify by corporate affiliations, Uniform Commercial Code (UCC) filings, shared addresses, business associate status, or possible business associate. We began our study with a specific productive sector: the top ten U.S. pork powerhouses, determined by the number of sows associated with each entity (See Table 1). From there, we used the subscription-only database LexisNexis Public Records to gather LexisNexis SmartLinx Comprehensive Business Reports that pertained to each of these entities as well as all the related business entities uncovered through these reports. The LexisNexis Corporate Affiliation Reports provided data on the organizational structure of public companies such as parent companies and subsidiaries. Between late 2019 to early 2020 (the top ten pork powerhouses stayed the same during this period), we compiled Comprehensive Business Reports for each of the top ten and from these reports, all of the entities with shared addresses, business associates or possible business associates, or named on a UCC filing, which secure loans between creditors and debtors. Lexis Nexis utilizes a proprietary algorithm to identify business associates and possible business associates in its SmartLinx reports. Our analysis of these business reports expanded the initial 10 firms to include 559 entities exhibiting 720 financial ties.

Table 1 Top 10 pork powerhouses (Freese 2020)

2020 ranking	Company/headquarters	# of Sows 2020
1	Smithfield Foods/WH Group Smithfield, VA/China	915,000
2	Seaboard Foods Shawnee Mission, KS	340,000
3	Pipestone System Pipestone, MN (plus 42,674 sows in Mexico and 67,280 in China)	274,245
4	Iowa Select Farms Iowa Falls, IA	242,500
5	The Maschhoffs Carlyle, IL	187,000
6	Prestage Farms Clinton, NC	178,000
7	JBS Greeley, CO/Brazil	169,000
8	Carthage System Carthage, IL	165,600
9	AMVC Management Services Audubon, IA	152,000
10	Christensen Farms Sleepy Eye, MN	143,000

Source Successful Farming (2020), using company provided data

Because some of the business associates that we identified predate mergers, we replaced firms that no longer exist with their current, post-merger form. In the case of the FCS, we consolidated all affiliates into the FCS, reflecting its state chartering and allocation through federal law. Some other entities had different tax identification numbers but the same name, and we consolidated these entities into one. In addition, some entities had punctuation differences that initially made them seem distinct, but we corrected them for merging purposes. We also had to remove some firms because we did not have sufficient information. For example, some firms were listed as business associates, but did not have reports available to confirm their existence.

We then ran a series of analyses centered around three questions:

RQ1 Who are the key players in Big Ag?

RQ2 Does the network mirror a core-periphery structure?

RQ3 How consolidated are network ties in Big Ag and Big Finance?

We completed a two-mode network analysis for the questions. A two-mode network is a type of network in which there are (a) two sets of distinct nodes (e.g., people and events) and (b) at least one relationship connecting those two types of nodes (e.g., the attendance of people at each event).

The two-mode network is primarily useful because it reveals a structure between otherwise seemingly disconnected types of nodes (Borgatti et al. 2013). In our analysis, mode one is the top ten pork producers, mode two is the firms, and the links are the top ten pork corporate relationships with such firms that we identified through business reports. For RQ1, we completed a key player analysis, which computes various indices of network centrality to find out what key pork producers and firms are in the network. For RQ2, we computationally derived a set of core nodes and compared them to an idealized core structure. For RQ3, we examined the distribution of links from the pork powerhouses to all other firms.

Findings

RQ1: Key pork powerhouse players

One way to identify market network power is through what Borgatti (2006) called *key player analysis*, which uses network-based metrics to assess importance. For instance, the power of a private firm derives not only from how much money it lends, but also how many firms it lends money to. Here, such relational power, measured through the sheer number of ties, may give an organization more perceived prestige (Wasserman and Faust 1994). Likewise, an organization may gain the advantage of acquiring social capital because such organizations are highly embedded in the system and can exploit resources through the volume of their connections (Powell et al. 1996). Following Borgatti and Everett's (1997) suggestions for assessing centrality in two-mode networks, we report (1) degree centrality, (2) eigenvector centrality, (3) closeness centrality, and (4) betweenness centrality. Degree centrality is the total number of ties that each pork powerhouse has with existing firms. Eigenvector centrality accounts for the degree centrality in each affiliated firm. A higher number indicates that the pork powerhouse is connected to likewise highly connected firms. Closeness centrality is related to geodesic distance (i.e., the shortest path length between any two nodes). It is common with tenets of the small world phenomenon (i.e., any two random nodes are indirectly connected). Here, a higher number indicates that each pork powerhouse is never too far away from another pork powerhouse through indirect connections. Finally, betweenness centrality serves as a measure of brokerage, indicating how often a node lies between two otherwise unconnected nodes.

To calculate these metrics for two-mode networks, we used *tnet*, an R package developed for two-mode and weighted networks (Opsahl 2009). To determine the extent to which some pork powerhouses were key players, we reduced the four-network metrics into a single factor using

principle component factor analysis. High loadings above 0.70 indicated to us that select pork powerhouses tend to be high on all four metrics. These include three entities: (1) Prestage Farms, (2) Smithfield Foods, and (3) Christensen Farms. Moderate loadings were positive, but below 0.50 for: (1) Seaboard Foods and (2) JBS. Finally, low loadings (i.e., below -0.50) indicate entities that were not key players: (1) Carthage System, (2) AMVC Management, (3) The Maschhoffs, (4) Iowa Select Farms, and (5) Pipestone Systems.

Discussion

Our SNA findings demonstrate that while the publicly traded firms remain powerful (JBS, Smithfield Foods and Seaboard Foods), SNA results show that private firms (i.e., Prestage Farms and Christensen Farms) are more relationally powerful. Their market network power is greater because they leverage more authority over more peripheral actors (see Fig. 1). Prestage Farms, the most powerful key player in our analysis, bottlenecks what appear to be producer-level LLCs, like Shady Oak Creek LLC and Bad Branch LLC. These blue entities include Limited Liability CAFOs, incorporated as LLCs that can constitute feeding, finishing, or gestation operations (Ashwood et al. 2014). Tightly constrained periphery (producer) and key (pork powerhouse) contract structures dominate the hog industry. Around 90% of growers (i.e. farmers or CAFO operators) do so under some form of contract, direct ownership, or advanced marketing agreement (Wise and Trist 2010).

However, there are other peripheral actors impacted by key player domination as well. Christensen Farms exhibits the most remarkable transformation in our analysis in terms of power. It moves up from the 10th position in terms of productive power to the 3rd most powerful firm in terms of relations (Table 2). Christensen Farms, which calls itself “one of the largest, family-owned pork producers in the United States” with “more than 300 contract producers” (Christensen Farms 2021), also constrains the power of other sectoral actors. For example, Christensen Farms' blue bouquet of periphery firms includes equipment producers, like Midwest Machinery, and more regional banks, like Morton Community Bank. Not only industrial animal facility operators, but these smaller banks and equipment companies throughout the network are bottled off (see Fig. 1).

RQ1: Key financial players

Addressing monopolistic and oligopolistic power requires paying attention to entities that have financial relationships to key players. Because a firm's degree centrality is constrained (i.e. a maximum of 10), it makes it difficult to measure network metrics like closeness and betweenness.

Fig. 1 Two-mode network of the pork powerhouses with key player and periphery firms

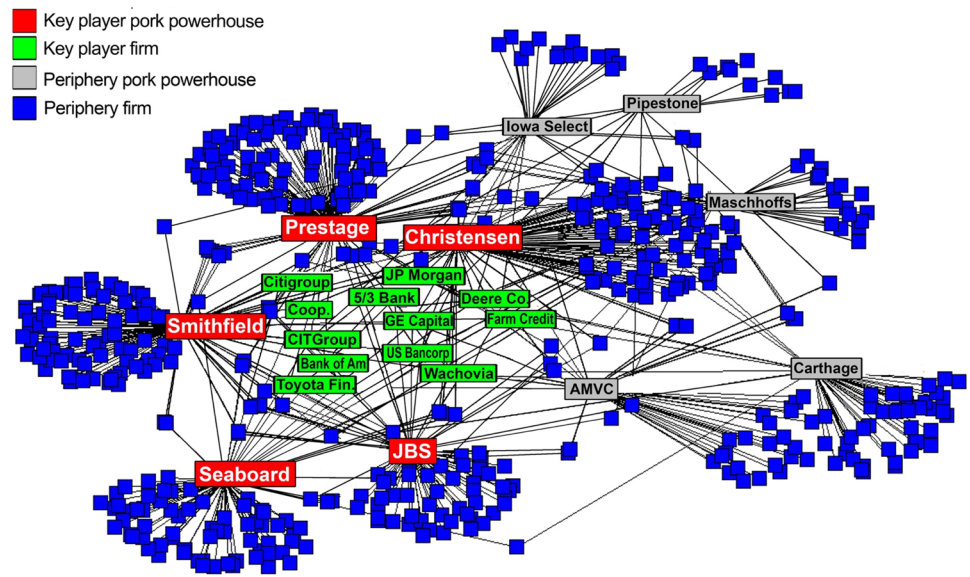


Table 2 Key player analysis of Top 10 pork powerhouses

Name	Degree rank	Power-house rank	Key player?	Degree centrality	Eigenvector centrality	Closeness centrality	Between-ness centrality
Prestage farms	1	6	Yes	137	.61	.15	12
Smithfield foods/WH group	2	1	Yes	124	.53	.14	7
Christensen farms	3	10	Yes	104	.35	.14	7
Seaboard foods	4	2	Moderate	91	.28	.10	0
JBS	5	7	Moderate	85	.32	.12	2
Carthage system	6	8	No	48	.08	.07	0
AMVC Management Services	7	9	No	42	.12	.09	0
The Maschhoffs, LLC	8	5	No	40	.13	.10	1
Iowa select farms	9	4	No	30	.12	.09	0
Pipestone system	10	3	No	19	.05	.06	0
			<i>Mean</i>	72.00	.26	.11	2.90
			<i>Median</i>	66.50	.21	.10	.50
			<i>SD</i>	41.57	.19	.03	4.25

As such, we conducted a core-periphery analysis to determine which firms can be classified as making up the core of firm affiliations in mode 2 (Borgatti et al. 2013). For this analysis, we used the software UCINET 6 (Borgatti et al. 2002). The analysis revealed that 12 out of the 549 firms in Mode 2 are significant key players, meaning they make up the bulk of ties between the pork powerhouses (see Table 3). Indeed, the average degree centrality of these 12 firms is 6.33, compared to an average of 1.19 from the remaining 537 firms ($F = 172.13, t = 29.51, p < 0.01$). The center of Fig. 1 demonstrates visually the importance of these (green) key players. Every one of the key player firms outside of the top ten pork powerhouses are financial firms, meaning they are a financial services firm or bank (Table 3). Those at the

other end of the network (those with the lowest degree centrality, eigenvector, closeness and/or betweenness) are more industrial, including Yokohama Tire, Wyoming Premium Farms, Wolfpack Farms, Wisconsin Lift, Wildcat Farms, and Wiese Material.

Discussion

The most central of these financial firms is the Farm Credit System (FCS). However, the literature on financialization tends to study novel forms of investment (Clapp 2014), precluding a focus on more traditional financial capital, such as secured loans provided by FCS. In part, the power of FCS is not surprising, as it now accounts for more farm debt than

Table 3 Key player firms

Name	Degree centrality	Eigenvec-tor centrality	Closeness centrality	Between-ness centrality
Farm credit system	10	.19	.26	0
GE Capital	9	.18	.26	0
Deere Co	8	.16	.26	0
US Bancorp	8	.18	.26	0
Wachovia Bank	8	.17	.26	0
Bank of America	6	.16	.26	0
CIT group	6	.16	.26	0
Toyota financial	5	.13	.26	0
Citigroup	4	.13	.26	0
Coöperatieve Centrale-Rabobank	4	.13	.26	0
Fifth Third Bank	4	.13	.26	0
JP Morgan Chase	4	.13	.26	0

at any time in recent history (Monke 2018). However, FCS's role in funding the largest pork conglomerates helps uphold the network. Take Smithfield Foods, the second most powerful player in our analysis (See Table 2). WH Group Ltd., the ultimate parent of the subsidiary Smithfield Foods, is traded on the Hong Kong Stock Exchange and run by Chinese executives. While WH GROUP Ltd. is publicly traded, 45.18% its ownership traces to the British Virgin Islands, with 27% of those securities held by the private firm Heroic Zone Investments Ltd. (Bloomberg Finance L.P. 2022a). WH Group Ltd., in sum, does not clearly fit the FCS's mandate to provide credit to "eligible persons in agriculture and rural America" (Farm Credit Administration 2022).

Bankers have criticized the FCS, saying the system creates the conditions for "unfair competition" (Monke 2018, p. 8; Reform Farm Credit 2020).¹ The American Bankers

¹ The specific advantages afforded to FCS can be more clearly parceled out via the 2004 attempt by Dutch Rabobank to purchase Farm Credit Service of America (FCSA), a bank within the overall FCS. FCSA at the time of the attempted merger was one of 18 lending associations in the Midwest region. FCSA held 8% of the overall Farm Credit System's \$91 billion loan portfolio (Monke 2004). If purchased by Rabobank, the FCSA would have lost its tax exemption on its real estate loan portfolio and access to System funds. In addition, shareholders would have owed capital gains taxes on their stock payments. Further, FCSA may have owed taxes on the \$800 million exit fee that Rabobank had on the table, along with a \$600 payment to FCSA stockholders (Monke 2004). While the merger did not go through, Rabo AgriFinance has continued its expansion into U.S. commercial farm lending, growing by 7% between 2015 and 2019 (Hrushka 2019). Other commercial lenders have followed suit and experienced levels of consolidation similar to FCS. The number of U.S. commercial banks has decreased by 41% between 2003 and 2018 (Hanson 2020). In the same period of time, the number of U.S. banks with over ¼ of their loan portfolio devoted to agriculture decreased by 24% (Hanson 2020).

Association's "Reform Farm Credit" website contends that FCS gave only 16% of its loans to small farmers. In addition, the organization contends that FCS paid only a 0.73% tax on its \$38 million of profits in 2017 and critiques FCS's loans to multinational companies, including a \$725 million loan to Verizon to purchase a European cellular company (Reform Farm Credit 2020).

Like the FCS, banking too has consolidated dramatically, likewise influencing consolidation in agriculture. The high degree centrality of financial firms in the network may be in part explained by the recently acquired capacity of banks to engage in commodity trade and production. GE Capital, which we identify as the second key financial firm in hog production (Table 3), is a subsidiary of General Electric and allows "a wide variety of commercial firms to own and operate deposit taking institutions" (Omarova 2013, p. 278). Financial holding companies have received special permission from the Board of Governors of the Federal Reserve System to trade physical commodities when the Board deems it as complementary to their financial activities of trading and dealing in commodity derivatives (Omarova 2013). Omarova notes that there is an "inherent flaw" in the concept of complementarity as it fails to limit the expansion of banking into commercial business, which may help explain our findings (p. 307). CitiGroup, which we identify as the ninth key player in the hog network, in 2003 became the first holding company to receive such permission to trade and deal in commodity derivatives. Bank of America (ranked sixth) and Wachovia (ranked fifth) gained permission in 2006–2007 (Table 3). These are also firms that were "bailed out" during the financial crisis of 2008 (Johnson and Kwak 2010, p. 11). Omarova (2013) notes that public disclosure of precisely how these financial entities invest is limited. Our method identifies these financial firms as creditors in the hog network through UCC filings.

RQ2: Core-periphery structure

Systemic risk and dependency take two primary forms in our results. The first is the bottlenecking of power, where key pork powerhouses and financial firms limit other peripheral actors' ability to access the network. This impacts multiple sectors, including regional banks, construction and equipment companies, and CAFOs. Further, it points to those left out of the network altogether—unincorporated, sole proprietor farmers and similarly small businesses. However, there also potentially exists a systemic level of dependency between key players, meaning the disabling of one key player renders the others vulnerable to collapse. For example, the 2021 cyber-attack of JBS shuttered operations at dependent processing plants.

Core-periphery structures are the basis for a significant range of social theories, including World Systems Theory

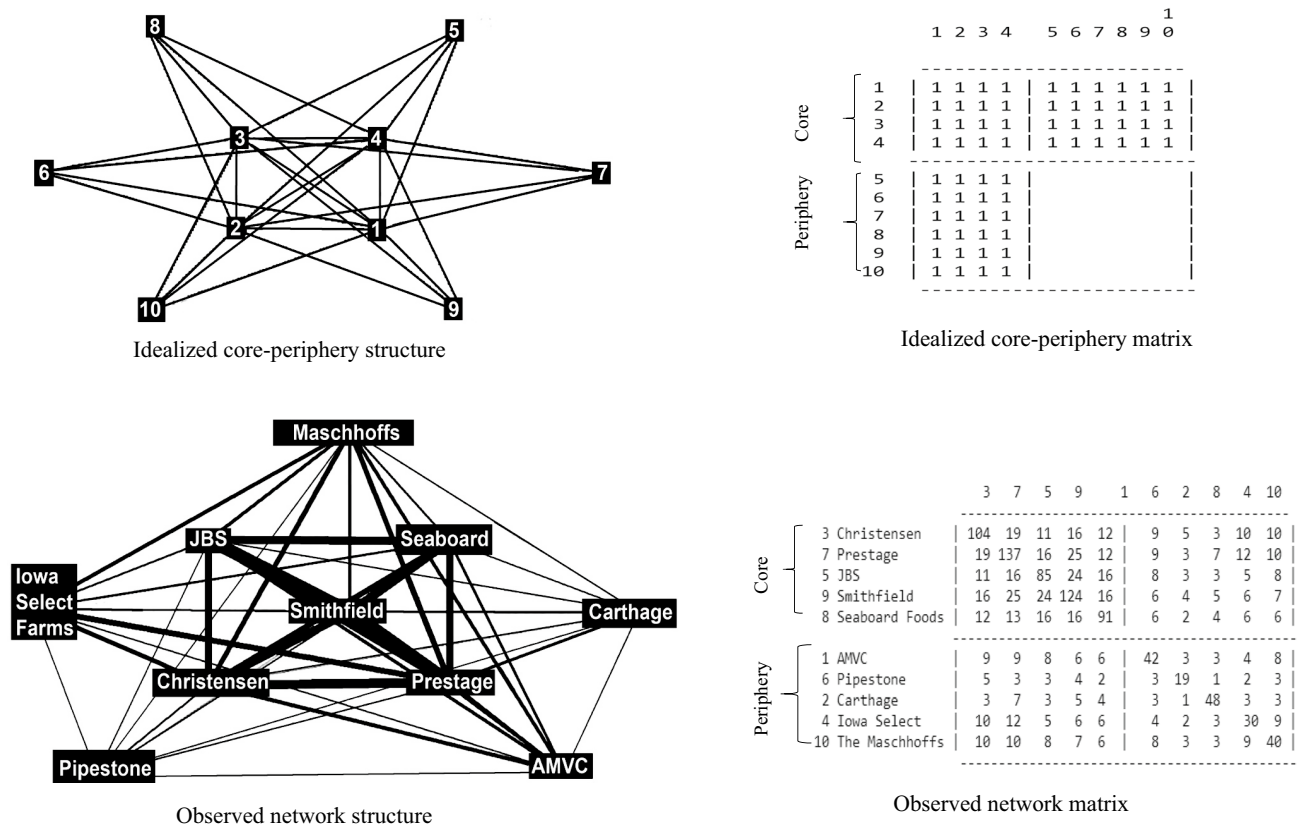


Fig. 2 Core-periphery analysis. Correlation between ideal and observed = .90

(Wallerstein 1974) and various resource dependency theories (Ferraro 2008). Core-periphery studies, while still important at the international level, also exist within nation states. Especially in the case of capital investment, networks cross nation-state and intrastate boundaries (Sklair 2001), and create peripheries within core countries and between them (Ashwood and MacTavish 2016).

With respect to SNA, Borgatti and Everett (1999) put forth a method to determine if observed network structures represent core-periphery structures by computationally deriving a set of core nodes and comparing it to an idealized core structure (see Fig. 2). To try to identify these relationships in the market power network, we identify the core-periphery structure as that which consists of, “two classes of nodes, namely a cohesive subgraph (the core) in which actors are connected to each other in some maximal sense and a class of actors that are more loosely connected to the cohesive subgraph but lack any maximal cohesion with the core” (Borgatti and Everett 1999, p. 377). In this case, a tie between any two pork powerhouses represents a shared corporate finance relationship with a common firm.

We found a significant core-periphery structure is evident with a 0.90 network correlation with the ideal core-periphery structure. Individually, a metric called *coreness*

can also be measured to determine how well a node fits in the core (Borgatti and Everett 1997), referenced as *C*. This structure is maximized when a dense set of five pork powerhouses are placed into the core: (1) Smithfield Foods ($C=0.54$), (2) Prestage Farms ($C=0.50$), (3) JBS ($C=0.40$), (4) Christensen Farms ($C=0.35$), and (5) Seaboard Foods ($C=0.31$). The other five remaining organizations were classified as the periphery: (1) The Maschoffs ($C=0.16$), (2) Iowa Select Farms ($C=0.15$), (3) AMVC ($C=0.14$), (4) Carthage ($C=0.04$), and (5) Pipestone Systems ($C=0.01$).

The effect size correlation provides a means to think about the way the extreme core dominance of the power network puts the food system at risk (Cohen 1992). Anything above 0.5 (i.e., a large effect size) suggests vulnerabilities for the entire network if something happens to the core (Fig. 2). A 0.3 to 0.5 correlation demonstrates moderate dependency, and 0.3 showing little vulnerability. The market network helps identify an alternative tool to calculate market power outside of limited production specific measures like CR4 and HHI that miss matters of fairness, choice, and access, and more aggregately, systemic level risk in the food system.

Discussion

While the key pork powerhouses bottleneck the power of peripheral firms, these core players (which coincide with key and moderate players in Table 2) are simultaneously dependent on one another. Christensen Farms is the largest owner of the Triumph Foods plant and disclosed in an editorial that Triumph Foods holds a 50% partnership in Seaboard Triumph Foods, LLC of Sioux City, Iowa (Christensen Farms 2020). Christensen Farms exhibits in our analysis 12 ties to Seaboard Foods (See Fig. 2 observed network matrix). This interdependency makes focusing on one firm or farm market ill-suited and suggests the importance of examining network levels of power.

These core and periphery dynamics suggest that more risky elements of production and finance may be organized into private firms while other firms remain the more public brand of investment and retail. Prestage Farms likewise appears to be a central private partner to Smithfield Foods, the second most powerful key firm, but one at the very center of the core (see Fig. 2 and Table 2). Prestage Farms is technically headquartered in North Carolina, but the firm also has operations in Iowa, Mississippi, and Oklahoma. The interfirm ties between Prestage Farms and Smithfield Foods includes Prestage's use of Smithfield's processing plant, in addition to operating two of its own: Prestage Foods of Iowa and Prestage Foods of North Carolina (for poultry) (Prestage Foods 2021). Prestage Farms also is one of the country's largest turkey producers (Graber 2021). Concerning hog production, the public relations manager of Prestage said at one time that the firm was Smithfield's largest contract grower of hogs in North Carolina and used Smithfield's processing plant (Deacon 2014). However, the same manager said the company prided itself on not being bought out by Smithfield, suggesting there remains some important separations of power that we cannot fully discern because private firms like Prestage do not have to disclose as much information as firms like Smithfield Foods, which is a private subsidiary of the public firm WH Group Ltd. (Deacon 2014). In addition to its direct ties to Smithfield, Prestage also ties into Murphy Brown LLC, which lists Prestage in its Comprehensive Business Report as a business associate. Murphy Farms LLC and Murphy-Brown LLC are known hog contract growers and subsidiaries of Smithfield Foods (Bloomberg L.P. 2022b). Murphy-Brown has recently been subject to a series of high-impact litigation suits in North Carolina, centered around civil-rights as well as nuisance litigation.

While our network analysis shows dependency between the pork powerhouses, they continue to be treated independently in the measurement of CR4 and HHI for pork slaughtering specifically. What's notable is that even when treating these firms as independent and self-actualizing, concentration is high according to these traditional measures of market

power. In 2010, Smithfield (31%), Tyson (17%), JBS Swift & Company (11%), and Cargill (8%) together controlled 67% of the pork slaughtering market (Wise and Trist 2010). As of 2007, CR4 calculations put hog production at 37.4%, with Smithfield (19.7%), Triumph Foods (6.6%), Seaboard Corporation (3.5%), and Iowa Select Farms (2.5%) (Wise and Trist 2010). Stopping there, however, leaves corporate finance unaccounted for. SNA offers a means to identify financial ties between these firms through mechanisms like loans and subsidiaries and thus identify interdependencies between farm markets. Control over slaughtering, for example, shapes control over growing, with Prestage having 25 ties to Smithfield (see Fig. 2 observed network matrix), the most interfirm ties; and Triumph Foods processing facilities co-owned by Christensen Farms and Seaboard Foods.

RQ3: Consolidation in agriculture and finance

Key player as well as core and periphery analysis provide important insights into access, dependency, and power. However, they do not measure the extent of consolidation in the overall network and the capacity of key players to become even more powerful. Most importantly, we do not have a sense of whether or not the core-periphery and key player distribution are outside of what would be typically expected in any given network.

To examine whether or not the distribution of ties from pork powerhouses to firms represents some sort of consolidation, we tested five different plausible distributions. The first distribution is the standard normal distribution, where most values are typically in the middle forming a bell-curve. Second, we tested for four types of skewed distributions: (1) Log-normal, (2) Poisson, (3) Exponential, and (4) Power-law. Our analysis reported two values: (1) a Kolmogorov–Smirnov (KS) statistic that indicates the extent that the data fits the distributions and (2) a corresponding probability value. The higher the KS statistic and the lower the probability value, the more confidence we have that the observed data *does not* fit the distribution well and another one is more appropriate. As such, the distribution with the highest probability value, for our purposes, may be the most plausible distribution (see Fig. 3).

The results indicate that we can confidently rule out a standard normal distribution, which would be a typical characterization of a decentralized/egalitarian network where most nodes have a moderate amount (i.e., five in our case) of links ($KS = 0.46, p < 0.01$). As such, what kind of centralized and skewed distribution is evident? Here, we can also confidently rule out the Poisson ($KS = 0.05, p < 0.01$) and exponential ($KS = 0.06, p < 0.01$) distributions as well. However, we cannot rule out a log-normal ($KS = 0.01, p = 0.16$) or power-law ($KS = 0.01, p = 0.42$) distribution. Although the KS statistics are nearly identical ($t = 1.10, p = 0.27$), the

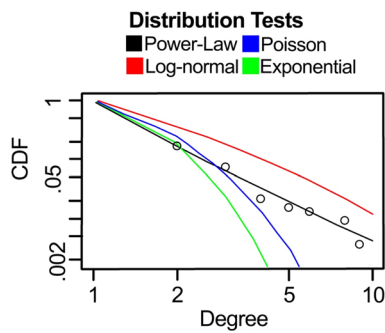


Fig. 3 Distribution tests of market network power in hog production. CDF stands for cumulative distribution function

higher probability ($p=0.42$ vs. $p=0.16$) of the power-law distribution leads us to conclude it is the most plausible distribution. In other words, we are about two and half more times confident that the distribution resembles more of a power-law than a log-normal distribution.

Discussion

Our findings suggest that the hog network market is highly consolidated, especially when compared other forms of distribution (see Fig. 3). In effect, this means of all the distributions tested, power-law distributions are by far the most skewed (Clauset et al. 2009). The prevailing power-law distribution is defined by rich-get-richer processes in which already popular nodes tend to be more likely to receive new ties (Barabási and Albert 1999). This means the distribution of the market network power is highly skewed with the presence of a small number of hubs containing the lion's share of links and the vast majority containing small degree counts.² Key pork powerhouses, like Smithfield and Prestage Farms, and financial firms, like FCS, are not just dominating now. The structure of the network leaves them positioned to become even more powerful in the future.

² Mathematically, power laws are roughly defined by identifying the number of nodes with any given degree count (x) through an exponential relationship (i.e., scale-free): $\frac{1}{x^2}$. For instance, the number of nodes with a low degree count (e.g., $\frac{1}{2}$) would represent a significant percentage of all nodes ($\frac{1}{2^2} = 0.25$). If applied to a larger degree count (e.g., 10), the formula would produce a much lower percentage of nodes ($\frac{1}{10^2} = 0.01$). Using a power law degree distribution function, the program generated a goodness of fit (GOF) statistic using bootstrapping methods (Clauset et al. 2009). The null hypothesis (H_0) is that the data is generated from a power-law (i.e., high probability values) while the alternative hypothesis (H_1) is that the data is not generated from a power law distribution and another shape is more appropriate (Fig. 3).

Conclusion and limitations

Our relational analysis of the broader network of firms in industrial pork production reveals the interplay between Big Ag and Big Finance. Of the 549 firms in the network, outside of the pork powerhouses themselves, financial firms are the key players. FCS is at the helm. Like a near century ago with its first articulations, the FCS enables or disables certain types of agriculture by choosing to finance it. Currently, there is no mandated public disclosure of FCS funding of corporate entities—domestic or international—that receive loans from this government sponsored enterprise. Public disclosure and transparency provide an important first step to ensure democratic accountability for finance. Likewise, other forms of public subsidization enable the dominance of the pork powerhouses. In Iowa, Mary Ann Christensen, a board member of Christensen Farms, made a \$25,000 gift to the state's governor a month before the firm received \$1.86 million from the Iowa Disposal Assistance program in payments for hogs euthanized during to COVID-19, \$40 a head (Associated Press 2021; Daily Beast 2021). Christensen actively encouraged Missouri's director of agriculture to keep its plant open during the COVID-19 outbreak (The Oklahoman 2020). Prestage has made campaign contributions to North Carolina's commissioner of labor as well as the Governor of Iowa (Critchfield 2020; Foley 2021).

Only focusing on corporate finance with the clearest government mandates, however, risks overlooking the non-agricultural actors key in market network power. Currently, publicly traded firms face some required Security and Exchange Commission disclosures about security owners, but private firms mostly do not—meaning firms that are not publicly traded. Since private firms can be major holders of publicly traded companies (i.e. WH Group Ltd.'s largest holders are private firms), even publicly traded firms are missing crucial data on their ultimate beneficial owners. The level of interdependency between firms may be even more extreme than what we document here, but even with our paid subscription to LexisNexis, our data does not identify ultimate beneficial owners. There is some movement to require disclosures of as much. The National Defense Authorization Act, passed in 2021, includes the Corporate Transparency Act and Section 885. Together, these laws require disclosing foreign-owned shell companies' ultimate beneficial owners to the Financial Crimes Enforcement Network, and separately, federal contractors to disclose ultimate beneficial owners (Stretton 2021; Valenstein et al. 2021). However, data required through the Corporate Transparency Act will only be available to law enforcement agencies, but not the public. Corporate loan and subsidy recipients of government related programs or enterprises, like FCS and other

agricultural ones, are also notably absent from required disclosures of ownership.

These private or public firms may also be engaging in physical commodity trading, which adds an additional layer to corporate finance's obfuscation of its control over markets. However, this is difficult to prove without minute-level evidence, which current regulations do not require. There is, in fact, a "near-absence of reliable, detailed data on the precise nature and full scope of U.S. banking organizations' physical commodity operations" (Omarova 2013, p. 297). Forward contracts for future delivery of physical commodities, for example, can be treated sometimes as cash trades or financial instruments, whatever helps sidestep regulations and policy that may seek to limit these kinds of productive investments (Omarova 2013). Our methodology does not identify the forms of securities firms use for investment. While our research can show these relationships exist between entities (which we see as an important improvement on what we currently know about power and finance in industrial animal production), the plethora of ways in which financial holding companies exert control over agricultural production warrants further study.

Relatedly, our U.S.-centric analysis poses some limitations to understanding the power of the corporations we study. Our dataset does not extend to non-U.S. public documents. While our data is rich in detail and reveals important new content domestically, the key player analysis could change with other public records from other nations. Nonetheless, many of the financial key players in hog production that we identify in our paper—GE Capital, Citigroup, Bank of America, JP Morgan Chase, and Wachovia—are major investors in other industries and nation-states (Omarova 2013; Valati et al. 2011; Clapp 2019). While production has localized impacts and material needs, finance flows boundlessly. By extension, our findings confirm the hegemonic power of corporate finance, whether historically through banks or more recently through novel investment mechanisms (Green 1987). Big Ag depends on Big Finance.

Our findings suggest that sector specific studies of agricultural monopolies and oligopolies, and likewise monopsonies and oligopsonies, overlook the extensive role of finance and the complex corporate, organizational structures that shape market power. Our network approach to market power provides a means to identify corporate finance relationships through network structure, dependency across sectors, and key players (like finance). Power law-distribution tests, key player analysis, and core-periphery structures offer plausible metrics to alternatively measure undemocratic forms of economic organization.

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