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Consolidation and Concentration in U.S. Meat Processing: Updated Measures Using Plant-Level Data

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Abstract

Significant plant- and industry-wide disruptions have occurred in the U.S. meatpacking industry during the past several years. The result has been a reinvigorated interest in the possibility that industry concentration has facilitated anticompetitive behavior and a torrent of public policy proposals to improve resiliency. In this paper, we provide a contemporary synopsis of meat processing concentration statistics with the use of annual plant-level food safety and inspection service (FSIS) data that cover all federally inspected livestock processing facilities in the U.S. for the past 30 years. Beyond considering traditional concentration measures (e.g., CR4 and HHI), we exploit the plant-level nature of the data and consider trends in processing facility consolidation, ownership changes, and how regional procurement markets have changed over time.

Keywords Concentration · Consolidation · Livestock · Meatpacking · Poultry

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1 Introduction

Meat processing ownership concentration has been at the center of market power research inquiries, public policy debates, and antitrust lawsuits in the U.S. since the 1920s. Concentration ratio measures—the share of an industry's output that is accounted for by a specific number of firms—are widely used as an indicator of an industry's structure at one point in time and of structural change over time.[1] National concentration has increased markedly since the 1960s with merger and acquisition activity peaking during the late 1970s and early 1980s (MacDonald et al., 2000; Nguyen & Ollinger, 2006).[2] Underlying the rising concentration ratio measures are a related series of changes in industry organization that—taken together—have led to dramatic consolidation with outcomes that reverberate today.

According to MacDonald et al. (2000), between 1980 and 1995, steer and heifer slaughter experienced an unprecedented increase in the four firm concentration ratio (CR4)—the largest increase in any manufacturing industry since the Census Bureau started reporting the CR4. Ward (2002) finds that—from 1976 to 1998—the CR4 in steer and heifer slaughter increased by more than three-fold. Similarly, Crespi et al. (2012) state that the CR4 increased by 136% from 1980 to 2010. By 2015, the CR4 had increased to 85%, moderating slightly thereafter (Crespi & Saitone, 2018). USDA Federal Safety and Inspection Service (FSIS) data indicate that in 2021 the CR4 for steer and heifer slaughter was 77% (See Figure 2, panel (a) below). During the 1980s and 1990s, economies of scale in harvest operations emerged as a driving force that underlay changes in processing plant size and location (MacDonald et al., 2000), solidifying much of the competitive and geographic landscape with which we are familiar today. However, familiarity has not resolved longstanding skepticism about the industry's competitiveness.

The notable trend in beef processing concentration has been mimicked in the pork industry—in 1963, the CR4 in hog processing was 33% (MacDonald et al., 2000). From 1980 to 2010, the CR4 in hog processing increased by 91% (Crespi et al., 2012). However, most of the increase in concentration in hog processing occurred later in time, as compared to beef.[3] In 2021, the CR4 for swine processing was 70%.

The broiler industry has experienced rising concentration as well; however not to the degree observed in beef and swine. In 1963 the CR4 for broiler processing in the U.S. was 14% (MacDonald et al., 2000). The percentage increase experienced from 1980 to 2010 was 59%—CR4 of 32% in 1980 compared to a CR4 of 51% in 2010 (Crespi et al., 2012). Like the beef industry, broiler processing experienced most of its increasing concentration in the 1980s and early 1990s. FSIS data for CY 2021 indicate that the CR4 in the broiler industry is 52%.

[1] The most often reported concentration ratio when surveying the economic literature on U.S. meatpacking is CR4—the market share of the four largest firms in the industry.

[2] During the 1980s business conglomerates liquidated the meatpacking operations that they had acquired during the 1970s. These plants were either shuttered or sold to "new" meat packers: e.g., ConAgra, Cargill (Ollinger et al., 2005).

[3] The CR4 in hog processing increased by only 35% from 1980 to 1995, compared to the 125% increase in beef during the same period (Crespi et al., 2012).

Economic theory suggests that industry concentration has the potential to create two opposing effects on output levels and input prices: Higher levels of concentration are often predicted to be associated with an increased potential for firms to exercise market power, which leads to lower levels of output and reduced prices that are paid to producers. Conversely increased concentration may enable firms to improve efficiency and achieve economies of scale. Numerous studies over the past several decades, have investigated these potential opposing effects as well as other aspects of competition. The general consensus of this body of work is that increases in consolidation and concentration have not suppressed the prices that meat packers have paid producers (Wohlgenant, 2013).[4]

Alongside concerns about market power, recent disruptions have raised concerns about the relationship between concentration and food system resilience. Policymakers and stakeholders have become increasingly skeptical about a market design that places 6–8% of national production in a single plant that might fail. Processing plant-level events—including Tyson Foods, Inc. discontinuing purchases of Holstein cattle at its Joslin, IL, harvest facility and Tyson's Holcomb, KS, beef processing plant fire that sidelined 6% of the nation's processing capacity—resulted in substantial increases in the farm-to-wholesale price spread (McKendree et al., 2021; Lusk et al., 2021).[5]

Most recently, the COVID-19 pandemic caused significant and unparalleled disruptions to the meat supply chain (Saitone et al., 2021; Taylor et al., 2020). As plant slowdowns and closures occurred, processors purchased fewer animals which caused producer prices to decline; simultaneously retail demand surged with retail prices following suit (U.S. Department of Agriculture, 2020).[6] Collectively, the events of the past five years have heightened scrutiny of the competitive landscape of U.S. meatpacking to unprecedented levels. This skepticism has led to a torrent of public policy proposals to improve U.S. meatpacking resiliency.

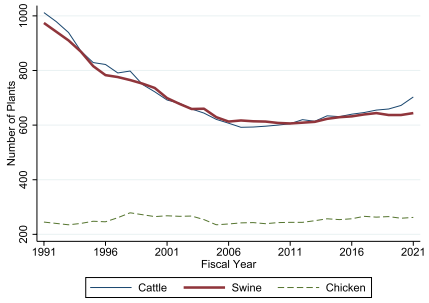
This paper seeks to contribute to the ongoing discussion of U.S. meatpacking industry structure, competition, and resiliency by providing a contemporary synopsis of U.S. meat processing industry concentration statistics using annual FSIS data for all federally inspected cattle, hog, and broiler chicken operations in the U.S. from 1991 to 2021.[7] FSIS data allow us to improve—both with respect

[4] Azzam and Anderson (1996), Ward (2002), U.S. Government Accountability Office (2009), and Wohlgenant (2013) jointly summarize the existing literature that is focused on the U.S. meatpacking industry's ability to exercise oligopsony power.

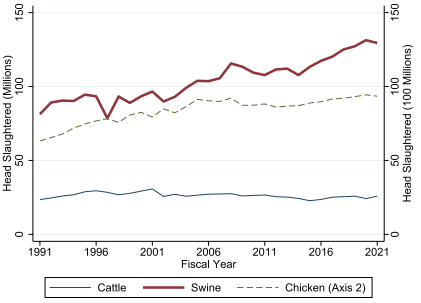
[5] The later event precipitated U.S. Senate Agricultural Committee hearings and a U.S. Department of Agriculture (USDA) investigation (U.S. Department of Agriculture, 2020).

[6] The Choice boxed beef cutout value increased 80% from early April to mid-May 2020 (U.S. Department of Agriculture, 2020). Figure 1, panel (d) shows wholesale prices for boxed beef, pork (composite), and broiler chicken from 2000 to present.

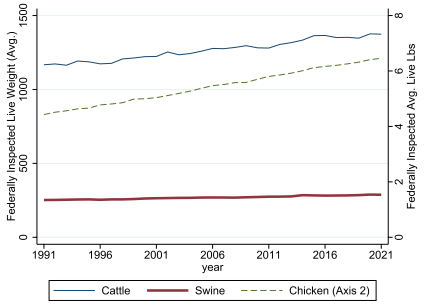
[7] The Federal Meat Inspection Act (FMIA) requires that all meat sold commercially be inspected and passed to ensure that it is safe, wholesome, and properly labeled. The USDA Food Safety and Inspection Service (FSIS) is responsible for providing this inspection. The FMIA requires inspection for any product that is intended for human consumption, wholly or in part, from the carcass or parts of any cattle, sheep, swine, and goat. Animals must be slaughtered and processed under Federal inspection, and the meat food products must be inspected and passed for human consumption. This inspection process generates counts and data for every animal that is slaughtered in every federally inspected meatpacking plant in the U.S. More information on inspection is available here: https://www.fsis.usda.gov/inspection/inspection-programs/inspection-meat-products.



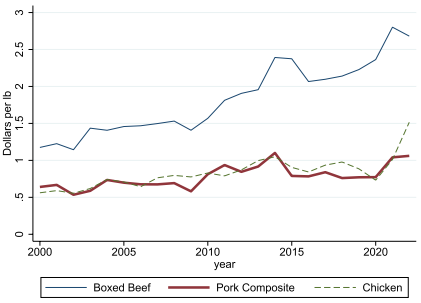
(a) Federally Inspected Plants



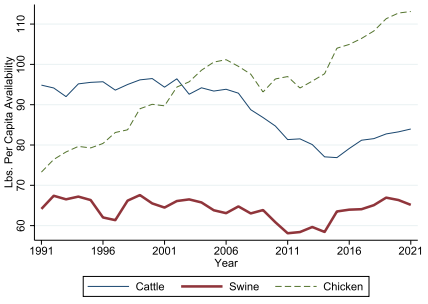
(b) Federally Inspected Production



(c) Federally Inspected Avg. Live Pounds



(d) Wholesale Prices



(e) Per Capita Availability

Fig. 1 Federally Inspected Processing Plants, Production, and Prices, 1991–2021.**Notes:** Panel **a** displays the no. of federally inspected cattle (steer and heifer), swine, and chicken processing plants in the U.S. from 1991–2021. Panel **b** displays the total no. of head slaughtered in these facilities. Panel **c** displays avg. live weight for cattle, swine, and chicken. Panel **d** displays wholesale prices for boxed beef cutout, pork cutout composite, and the 12-City composite for broilers prior to 2013 and the National composite for broilers thereafter. Panel **e** displays per capita (carcass-weight) availability

to accuracy and granularity—on previous measures that rely on census information or on data from the Grain Inspection, Packers, and Stockyards Administration (GIPSA). Because FSIS information is collected on a daily basis—by shift—for each federally inspected packing plant in the U.S., the data contain timely and accurate counts of animals and output, by plant, tracked over time, with the

consequent opportunity to track entry and exit. These data are not publicly available and were obtained via a cooperative work agreement with the USDA Office of the Chief Economist.

We extend our statistical inquiry historically to offer an opportunity for comparison with concentration measures that have been calculated in the past that often use alternative data sources. Due to the high degree of spatial and temporal coordination required to process livestock and poultry, regional procurement markets are often considered the most relevant for livestock producers and are also where buyer concentration levels far exceed the levels that are calculated at a national scale (Crespi et al., 2012; Love et al., 2010). Using plant location data, we are able to calculate regional concentration metrics using prototypical procurement radii; this adds a more nuanced investigation into concerns that have been raised by producers who have only two or three potential buyers for their livestock (U.S. Department of Justice, 2010).

Given that single- and multi- species ownership concentration has been at the center of policy makers' and Department of Justice investigations, we complement the FSIS data with National Establishment Time-Series (NETS) data in order to track processing plant ownership over time. The NETS data provides each processing facility's headquarters (i.e., ownership proxy) on an annual basis as well as address and Federal Information Processing Standards (FIPS) code information. Using these data, we are able to assess the frequency of ownership changes in addition to the impact that plant-level entry and exit has on total animals processed.

2 Processing Facilities and Production Levels

Meat processing plants are subject to an inherently skewed distribution. There are hundreds of very small slaughter facilities, with some handling 10 or fewer animals in a week. At the same time, a single large cattle plant might handle as many as 5000 head per day. Similarly, large hog and chicken plants hand 25,000 and 550,000 head per day, respectively. Panel (a) of Figure 1 displays the number of federally inspected cattle (steer and heifer), swine, and chicken processing plants in the U.S. from 1991 –2021.[8] The number of cattle and swine harvest facilities declined markedly between 1991 and 2007, leveling off thereafter. In 1991, there were 1,012 cattle processing plants and 974 swine processing plants. By 2007, this fell to 592 and 617 for cattle and swine, respectively. As of 2021, there are 703 federally inspected cattle processing plants and 644 federally inspected swine processing plants in the U.S. Over the same period of time, the number of chicken processing facilities has

[8] Throughout this paper, "cattle" refers to steers and heifers unless otherwise indicated. The majority of beef cattle that are slaughtered in the U.S. are steers and heifers. Younger animals have a different size and shape, which requires specialized processing operations/lines. Cows and bulls that are harvested are more commonly marketed directly from production operations after being culled from breeding herds. The outputs from these types of plants are also different with steer and heifer plants producing primal (i.e., muscle) cuts and cow and bull plants producing leaner beef that is often mixed with the trim from steers/heifers to create ground beef.

remained relatively stable. In 1991, there were 245 federally inspected chicken plants versus 262 in operation in 2021.

Panel (b) of Figure 1 shows that over this 30-year period, the number of hogs and broiler chickens slaughtered has increased substantially. Swine production has increased by 59% over the past 30 years; from 81.3 million head harvested in 1991 to 129.5 million head in 2021. Chicken production has increased by 48% during the same period: from 632 million head in 1991 to 934 million head in 2021.[9] In contrast to the other species that are considered, the number of cattle (steers and heifers) slaughtered has remained relatively stable over time, despite the substantial reduction in the number of processing operations. In 1991, 23.5 million cattle were slaughtered at federally inspected plants; this increased to 25.8 million head in 2021.

Panel (d) of Figure 1 displays the wholesale prices for beef, pork, and chicken from 2000 to 2022. These prices can be viewed in light of the trends in concentration and levels of production that are displayed in the other panels of the same figure. Panel (e) of Figure 1 displays per capita availability (on a carcass-weight basis) of beef, pork, and chicken meat. Over the period of analysis, beef availability per capita has fallen from 94.9 pounds per capita in 1991 to 84 pounds per capita in 2021. Pork availability per capita has remained relatively stable at approximately 64 pounds per capita over the period of analysis. At the same time, chicken availability per capita has increased from 73.3 pounds per capita in 1991 to 113.1 pounds per capita in 2021.

A substantial body of literature suggests that the cost advantages that are associated with size economies have driven the consolidation of beef and pork processing into larger processing facilities (Ward, 2002). MacDonald et al. (2000) details the early portions of this progression for cattle; in 1977, 84% of steer and heifer processing was conducted in plants that slaughtered less than 500,000 head per year. By 1997, the share of animals processed by that plant segment dropped to 20%, while plants that harvested more than 1 million head per year accounted for 63% of all production. A similar trend was observed in hog processing: In 1977, 38% of hogs were harvested in facilities that processed more than 1 million head annually; 20 years later 88% of hogs were harvested in facilities of this size (MacDonald et al., 2000). Anderson et al. (1998) found that plant exit during the 1990s was primarily driven by plant size (i.e., capacity), horizontal concentration, and lack of vertical coordination. The authors also found that smaller plants were more likely to exit markets that were already concentrated. Anderson et al. (1998) and others have remained agnostic about whether market power was responsible for driving small processing operations to exit. However, there is a general consensus in the academic literature that lower processing costs—due to concentration and scale economies—were accompanied by increased meat and livestock demand, and that the resulting effects on cattle prices (higher) more than offset the effect of higher concentration

[9] Additionally, slaughter weight for federally inspected chicken and—to a lesser extent—steer and heifers and swine have also been increasing over this period (see panel (c) of Figure 1). Thus, production has increased even more when evaluated on a per-pound basis.

on competition and cattle prices (lower) (Anderson et al., 1998; Azzam & Schroeter Jr, 1995; Wohlgenant, 2013).

Although the processing-plant-level consolidation that occurred in the 1990s and early 2000s was dramatic and swift, the current data and trends point to a more stable situation in recent history. Despite the highly publicized disruptions in meat processing that have occurred during the past five years, the aggregate number of processing facilities and total head slaughtered have been relatively stable.

3 Industry Ownership Concentration

3.1 Concentration Ratios

The comprehensive and disaggregate nature of the FSIS data allow for an assessment of ownership concentration beyond consideration of trends in CR4 over time. Panel (a) of Figure 2 reports concentration ratios (CR4 through CR20) for cattle (steer and heifer), swine, and chicken slaughter operations for fiscal year 2021.[10] The cattle processing industry has the highest concentration of the three—both when considering concentration in only a few firms (e.g., CR4) and when considering a broader number of firms (e.g., CR10 and CR20). Based on FSIS data, the CR10 and CR20 for cattle are 91 and 98%, respectively. Similarly, for the swine industry, the CR10 and CR20 are 90 and 96%. In contrast to cattle and swine, the broiler processing industry appears to have a lower level of concentration based on CR measures. The CR10 is 77%, and the CR20 is 94%.

With the progression of time, there has been a noted increase in ownership concentration across species (e.g., a single owner's having processing facilities for beef and also for swine). Panel (b) of Figure 2 reports concentration ratios on a cross-species basis. These are calculated by converting head slaughtered for each species to a monetary value by multiplying number of head by carcass-equivalent weight and wholesale meat price per carcass pound, where concentration ratios are based on firms' shares of the total monetary value across each industry.[11] Across all species, the largest four firms (CR4) account for control approximately 51% of the value of U.S. livestock production. The 10 largest firms (CR10) account for approximately 71% of the value of production, and the 20 largest firms (CR20) account for approximately 82% of the total value of production.

The Herfindahl-Hirschman index (HHI) is the sum of every firm's squared market share in an industry. Relative to other concentration measures (e.g., CR4), HHI

[10] Note that the analysis below is performed on the basis of the fiscal year, rather than the calendar year, due to FSIS data availability.

[11] Wholesale meat prices are obtained from the USDA Economic Research Service (ERS) "Livestock and Meat Domestic Data", available at https://www.ers.usda.gov/data-products/livestock-and-meat-domestic-data/.

is typically viewed as a superior measure because it weights the concentration by firm shares of sales in a manner that gives more weight to larger firms (Crespi et al., 2012).[12] The Federal Trade Commission (FTC) and Department of Justice (DOJ) use HHI when considering horizontal mergers in an industry.[13]

Panel (c) of Figure 2 shows the HHI for cattle (steer and heifer), swine, and poultry slaughter operations for 2021. As of 2021, the U.S. cattle processing industry has an HHI of 1580. The swine processing industry has an HHI of 1,439. This is higher than the HHI that was observed in 2007 by Crespi et al. (2012) for animal (non poultry) slaughter of 1,047. This is likely due to differences in data source and aggregation and not necessarily indicative of an increase during the intervening period of time.[14] In 2021 the chicken processing industry has an HHI of 969. This is an increase relative to what was observed by Crespi et al. (2012) for poultry processing: HHI = 738. In panel (c) of Figure 2, we also assess the cross-species HHI, which is calculated based on each firm's share of the total monetary value across the three industries.

3.2 Ownership Changes

Figure 3 sheds light on ownership changes over time in the U.S. livestock processing sector. We use plant-level information from the National Establishment Time Series (NETS) data on changes in the Data University Numbering System (DUNS) number for the owner of the plant.[15] Note that the NETS database does not distinguish between cattle and swine processing facilities. Thus, panel (a) of Figure 3 reports the number of plant-level changes in ownership for meat processing (excluding poultry). Panel (b) reports the number of plant-level changes in ownership for poultry processing. In panels (c) and (d) of the Figure, we calculate the share of total industry production that is subject to ownership turnover in a given year.

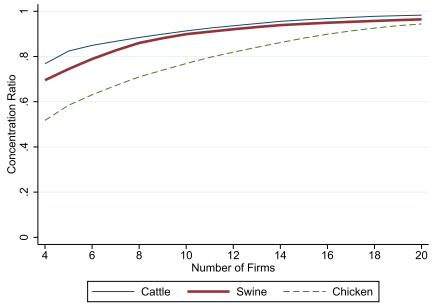
Figure 3 suggests that the cattle and swine industry jointly account for a much larger number of ownership changes than does the chicken industry. In panel (a), approximately 180 processing plants per year, on average, experienced a change in ownership (as measured by a change in owner DUNS number) between 1991 and

[12] Consider an example from Crespi et al. (2012): Consider two industries—A and B— that are each composed of five firms. Industry A's firms have the following percentage market shares: 50, 20, 10, 10, and 10, resulting in an HHI of 3200. The five firms in industry B have percentage shares of 30, 20, 20, 20, and 10, resulting in an HHI of 2200. The CR4 for both industries is 90%, but the higher HHI in industry A reflects the very large share of one of its firms.

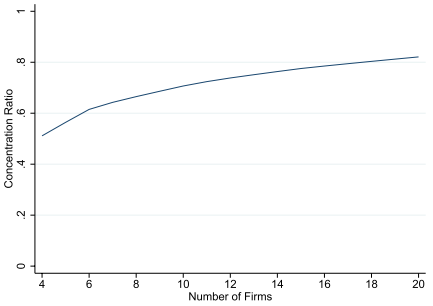
[13] The DOJ's horizontal merger guidelines for 1982–2009 divide the spectrum of market concentration, as measured by the HHI, into three categories: unconcentrated (HHI below 1000), moderately concentrated (HHI between 1000 and 1800), and highly concentrated (HHI above 1800). The proposed 2023 merger guidelines would reinstate these HHI division points.

[14] Crespi et al. (2012) calculate HHI with the use of 6-digit NAICS Industry Sales data. These data are aggregated such that the resulting HHI measure is representative of the concentration in beef and swine processing in aggregate.

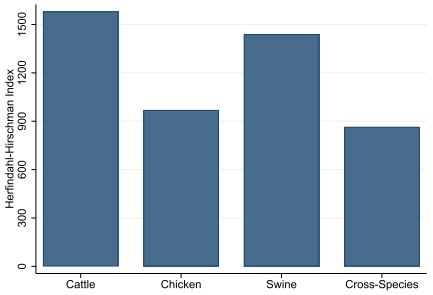
[15] The DUNS number is a unique nine-digit identification number that is assigned to all businesses in the U.S. by Dun & Bradstreet.



(a) Animal-Specific Concentration



(b) Sector-wide Concentration



(c) Sector-wide Concentration

Fig. 2 Ownership Concentration (2021). *Notes:* Panel **a** reports concentration ratios (CR4 through CR20) for cattle (steer and heifer), swine, and poultry slaughter operations for 2021 based on the number of head slaughtered in the fiscal year. Panel (c) reports the Herfindahl-Hirschman index (HHI) for cattle (steer and heifer), swine, and poultry slaughter operations for 2021. Panels **b** and **c** also report cross-species concentration ratios and HHI, respectively. These are calculated by converting head slaughtered for each species to a monetary value by multiplying number of head by carcass-equivalent weight and wholesale meat price per carcass pound, where the concentration ratio and HHI are based on firms' shares of the total monetary value across each industry. Underlying data are obtained from the USDA FSIS

2020. In contrast, in the chicken industry (panel (b)), only approximately 22 processing plants per year, on average, experienced an ownership change.

Over our period of analysis, major ownership changes also appear to have occurred much earlier in time in the cattle and swine processing industries relative to the broiler industry. Referring to panel (c) of Figure 3, we see that—in the cattle and swine processing industries—plants experiencing an ownership change accounted for 7% of annual industry sales, on average, between 1991 and 2000 with a maximum of nearly 20% in 1993. After year 2000, plants with ownership change amounted to 5% of industry sales, on average, in these industries.

In contrast, in the chicken industry, the period from 2005 to the present was characterized by a higher level of ownership turnover than was true of earlier periods. In 2011, sales from chicken plants that experienced a change in ownership amounted to nearly 23% of total industry sales.

4 Plant-Level Concentration and Turnover

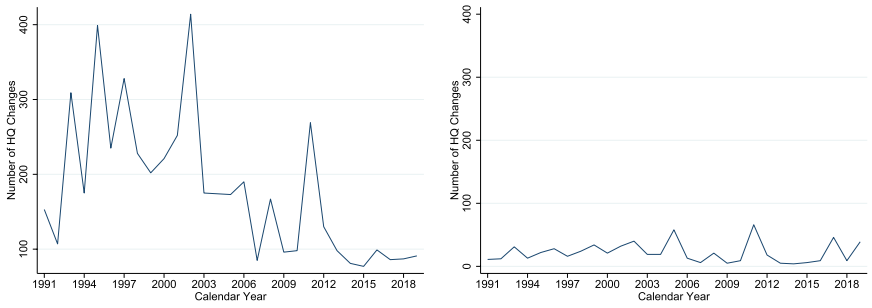
Plant-level production data are rarely, if ever, available to researchers for consideration and analysis. However, it has long been recognized that, due to the regional nature of livestock markets, individual plant decisions can affect the nature of competition in input procurement markets (e.g., Crespi and Sexton (2005); Crespi et al. (2012); McKendree et al. (2021)). In light of this, we use the available plant-level FSIS data to assess plant-level concentration and turnover—sale, entry, and exit—over time. Using the available FSIS data we consider plant-level concentration changes over time serve as a proxy for consolidation of processing into larger operations as well as a barometer of how firm-level concentration has evolved over the past 30 years.

Figure 4 presents the plant-level concentration ratios (CR4 up to CR100) for 1991 and 2021. The three meat types differ considerably with notable changes over time. Panel (a) of Figure 4 depicts the plant-level concentration ratios for cattle (steer and heifer). In 1991, the four largest plants accounted for 21% of industry production and 80% of the industry was accounted for by 28 plants. By 2021, the largest four plants account for 24% of the industry and 80% of production was provided by just 19 plants. The cattle industry exhibits significant plant-level consolidation which has intensified over the past 30 years. Panel (b) of Figure 4 presents the distribution of plant sizes in the cattle sector. In 1991 the largest 5% of plants processed more than 20 million head annually; the next largest 5% of plants harvested approximately 1 million head annually. The remaining 90% of plants slaughtered less than 100,000 head per year. Thirty years later, the distribution of plant sizes is largely the same with the largest 5% producing 25 million head per year, the next largest 5% producing approximately 1 million head per year, and the remaining 90% producing 100,000 head or less per year. This plant-level consolidation has direct implications with respect to the concerns about food system resilience that was discussed in Section 1. As the processing sector places a larger share of national production in a smaller number of plants, the stakes increase if one (or more) of these plants fails.

The chicken industry is remarkably different with the majority of plants being much more uniform in size. Panel (c) of Figure 4 shows that, in 1991, the four largest poultry plants accounted for 7% of industry production and the concentration ratio grows in a generally linear fashion as larger numbers of plants are considered. In 2021, the four largest plants accounted for 6% of the industry. In both 1991 and 2021, the largest 100 plants fell short of harvesting 80% of total industry production.

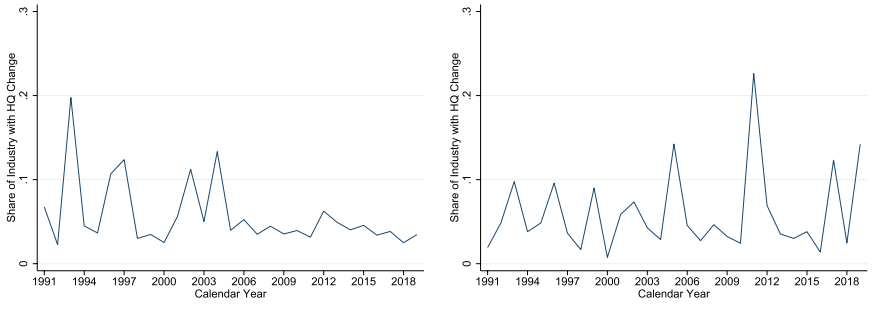
Panel (d) of Figure 4 displays the distribution of poultry plant sizes. This figure differs dramatically from the cattle plant size distribution as poultry plant sizes exhibit a more gradual decline from largest to smallest plants. In 1991, the largest 5% of chicken plants each accounted for over 100 million head slaughtered annually whereas the median plant produced over 29 million head a year. In 2021, the largest 5% of plants each accounted for over 150 million head per year whereas the median plant was producing in excess of 50 million head per year.

For the pork industry, the plant-level concentration is similar to cattle. Panel (e) of Figure 4 shows that, though less pronounced than cattle, there are a few large plants and a large number of small plants. In 1991, the largest four plants accounted



(a) Meat (Excluding Poultry)

(b) Poultry



(c) Meat (Excluding Poultry) M&A Share of Industry Totals

(d) Poultry M&A Share of Industry Totals

Fig. 3 Changes in plant-level ownership over time. *Notes:* This figure shows plant-level changes in the Data University Numbering System (DUNS) number for the owner of the plant. Panel **a** reports the number of plant-level changes in ownership for meat processing (excluding poultry). Panel **b** reports the number of plant-level changes in ownership for poultry processing. In panels **c** and **d**, we calculate the share of total industry production that is subject to ownership turnover in a given year. Underlying data are from the National Establishment Time Series (NETS) database

for 17% of industry production and 80% of industry production was generated by just 30 plants. In 2021, the largest four plants accounted for 20% of production and 80% of the industry was served by 24 plants. The pork sector exhibits a similar evolution as that of cattle where the industry evolved larger plants and a significant portion of the market accounted for by fewer larger plants.

In panel (f) of Figure 4 the distribution of plant sizes exhibits the same extreme-size dichotomy as cattle plants. In 1991, the largest 5% of plants produced in excess of 75 million head, the next largest 5% produced in excess of 4 million head per year. In 2021, the largest 5% produced 118 million head per year and the next largest 5% of plants produced over 10 million head per year. MacDonald et al. (2000) report that, in 1977, 38% of hog slaughter occurred in plants that harvested 1,000,000 or more hogs annually; in 1997, plants of the same size processed 87% of hogs in the U.S. Our data show that, as of 2021, pork plants that harvested 1 million or more hogs annually processed 92% of the industry production.

For both beef and pork processing, it appears that over the past 30 years while the largest plants have gotten larger—more head are processed in the largest 5% of plants—the share of animals that are harvested at the smaller processing facilities has remained stable (Figure 4, panels a & e). This is consistent with the observations of Lusk et al. (2021) who conclude—with the use of aggregate FSIS summary data—that smaller processing facilities are maintaining production levels.

Figure 5 shows plant-level turnover—the opening of new plants and the closure of existing plants—for the cattle, chicken, and swine processing industries over the period of analysis. This turnover is characterized in panels (a), (c), and (e) of Figure 5 as the share of total head slaughtered by new entrants in their first full year of operation after entry and in panels (b), (d), and (f) as the share of total head slaughtered by exiting plants in their final full year of production. Between 1991–2021, we observe 860 new plant entries and 1169 plant closures in the cattle processing industry. Of these, 443 plants both opened and closed within the period of analysis. Referring to panels (a) and (b), we see that—in spite of the numbers of entries and exits—this turnover represents a minimal share of industry production. On average between 1991–2021, new plant entries accounted for only 0.3% of annual, industry-wide cattle slaughter. Similarly, plant closures accounted for only an average of 1.1% of industry production. Consistent with previous estimates (Peel, 2021), we find that beefpacking capacity experienced a net loss in capacity of approximately 7% between 2010–2015.

Within the chicken processing industry, we observe 445 new plant openings and 438 plant closures between 1991–2021. Within this period of analysis, 324 new chicken plants both opened and subsequently closed. Panels (c) and (d) of Figure 5 suggest that—as with turnover in the cattle processing industry—these entrants and exits accounted for a small share of industry-wide chicken production. On average between 1991–2021, new plant openings (panel (c)) and closures of existing plants (panel (d)) accounted for only 0.6 and 0.7%, respectively of industry production.

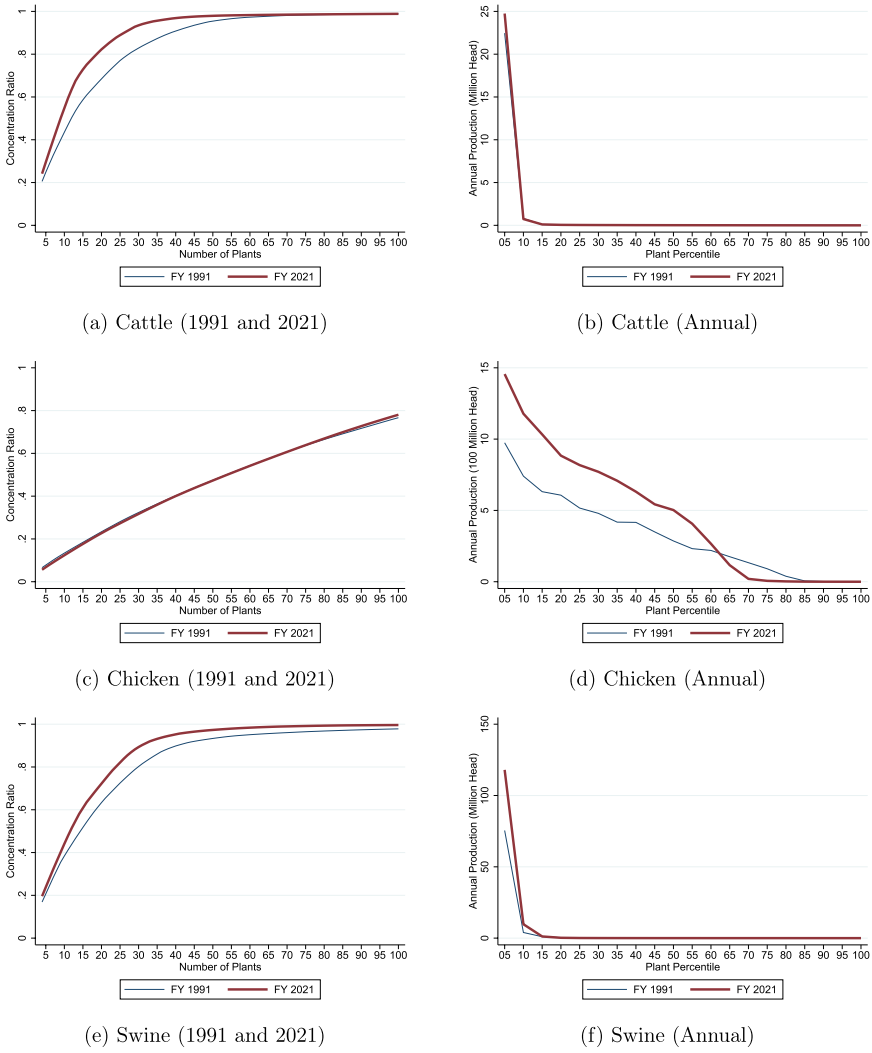
Turnover in the swine processing industry (shown in panels e and f of Figure 5) accounted for a slightly larger percentage of industry production than for cattle and chicken processing. Between 1991–2021, we observe the opening of 806 new swine processing facilities and the closure of 1,136 facilities, of which 437 facilities both opened and closed during the period of observation. On average, new plant entrants (panel (e)) and plant closures (panel (f)), respectively, accounted for 1.5 and 1.4% of annual industry-wide pork production.

In summary, entry and exit (plant turnover) occurs overwhelmingly among the fringe of small plants in all three livestock slaughtering industries.

5 Geographic Considerations in Livestock Processing

Figure 6 shows the location of the largest 100 federally inspected beef, pork, and chicken processing plants in FY 2021.[16] As is shown in the Figure, beef processing plants (panel (a)) are spread across the Midwestern and Western U.S., whereas

[16] Note that these data include only kill plants—processing plants that slaughter animals—and not plants that are responsible solely for further processing.



(a) Cattle (1991 and 2021)

(b) Cattle (Annual)

(c) Chicken (1991 and 2021)

(d) Chicken (Annual)

(e) Swine (1991 and 2021)

(f) Swine (Annual)

Fig. 4 Plant-Level Concentration. *Notes:* Panels **a**, **c**, and **e** present the plant-level concentration ratios (CR4 up to CR100) for cattle, chicken, and swine processing, respectively, for 1991 and 2021. Panels **b**, **d**, and **f** present the distribution of plant sizes in the cattle, chicken, and swine processing industries, respectively. These distributions are represented by reporting the annual production for plants in the 5th production percentile, the 10th production percentile, . . . , and the 95th production percentile for fiscal years 1991 and 2021

chicken processing plants (panel (b)) tend to be located in the Southern U.S., and swine processing plants (panel (c)) tend to be located in the Midwestern U.S.

As is shown in Figure 7, in Fiscal Year 2021, the four largest beef-processing states were Kansas (25.7% of production), Nebraska (24.8% of production), Texas (17.4% of production), and Colorado (8.8% of production). The four largest

chicken-producing states were Georgia (13.8% of production), Alabama (12.4% of production), Arkansas (10.6% of production), and North Carolina (9.8% of production). The four largest swine-producing states were Iowa (30.3% of production), Minnesota (9.5% of production), North Carolina (9.2% of production), and Illinois (9.2% of production). Appendix Figure A2 characterizes the evolution of geographic concentration in the beef, chicken, and swine industries at the state level and at the level of the agricultural statistics district (ASD) from 1991 to 2021.

In summary, our data suggest that the beef and swine sectors have become slightly more geographically concentrated, whereas the chicken processing industry has become slightly less geographically concentrated. These findings hold both at the state-level and at the ASD level.

To shed light on the extent to which spatial competition has evolved over the period of analysis, we calculate—for each plant in our database—the number of other processing plants operating within a 150-mile radius of the plant.[17] Of course, as we have discussed in Sections 2 and 4, the vast majority of packing plants are very small. And regional competition measures that are strictly based on plant counts may be problematic. Accordingly, we broaden the analysis in two ways. First, in addition to the number of plants within the 150-mile radius, we also assess the total number of head processed by other slaughter facilities within the 150-mile radius. Next, we limit the analysis to only the largest 100 plants for each species. Using this data sample, we report the evolution of regional competition both in terms of number of plants and number of head slaughtered at other facilities within the 150-mile radius.

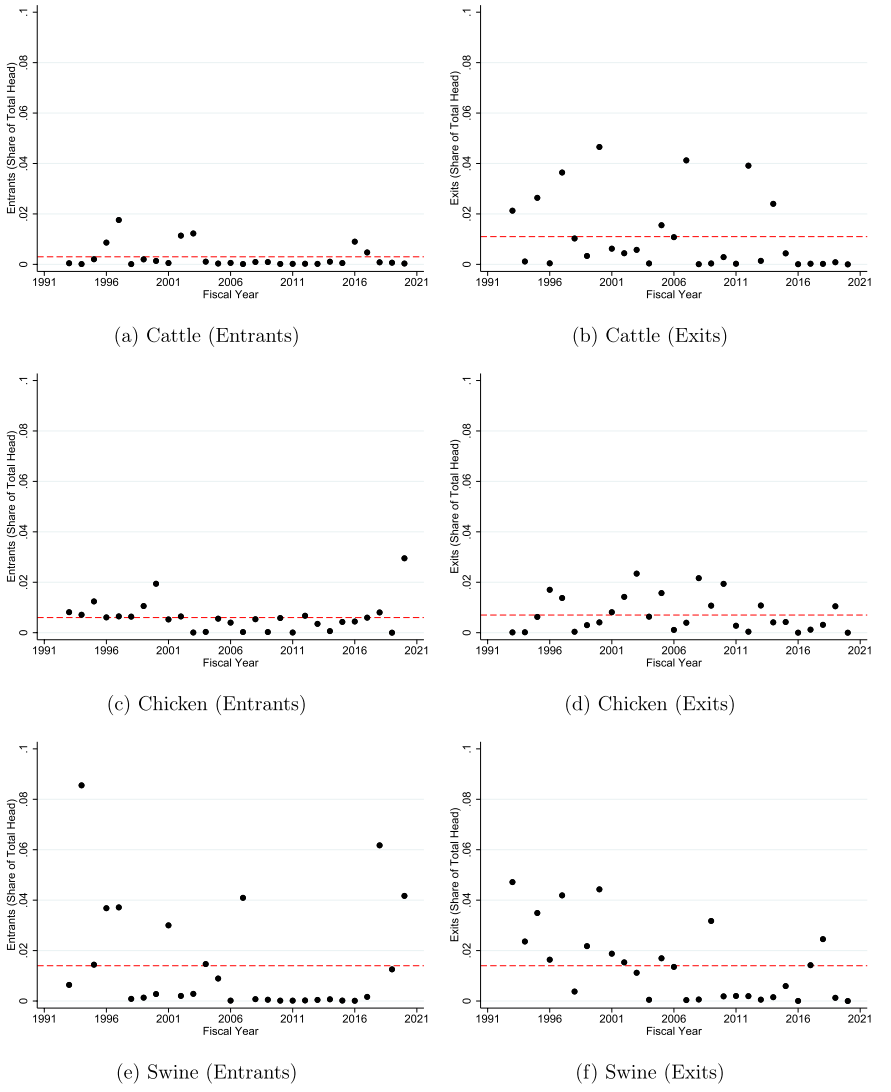
Table 1 summarizes these measures of spatial competition. For fiscal years 1991 and 2021, we report the mean, median, minimum, and maximum number of other processing plants and the number of total head processed by other plants within a 150-mile radius from a given processing plant.

The results in Table 1 suggest that spatial competition has generally increased from 1991 to 2021 in each industry. In 1991, the median beef processing plant had a total of 14 competing plants processing a total of 25.6 thousand head within a 150-mile radius.[18] In 2021, the number of competitors within this same radius increased to 16 for the median-sized beef processing facility with a total of 39.1 thousand head harvested by competitors. The median-sized swine processing plant faced 16 competitor plants in 1991 and 2021, but the number of head processed in these competitor plants increased from 1.1 million head in 1991 to 2.0 million head in 2021.

As is shown in the bottom portion of Table 1, this trend is similar when we limit the analysis to the largest 100 plants for each species. In 1991, the median beef

[17] Note that the 150-mile radius is chosen for the purposes of being conservative. Prior literature has suggested that the catchment area for broiler plants is a 30-60 mile radius (MacDonald, 2018). Ward (1990) found that most cattle are purchased for a specific plant from within a 100-mile radius of that facility. Within this analysis, we do not control for the possibility that one or more other plant within the 150-mile radius may also be owned by the same company as the plant at the center of the 150-mile radius. Thus, these estimates may overstate the intensity of competition.

[18] Complete spatial competition density estimates for fiscal years 1991 and 2021 are shown in Appendix Figure A3.



(a) Cattle (Entrants)

(b) Cattle (Exits)

(c) Chicken (Entrants)

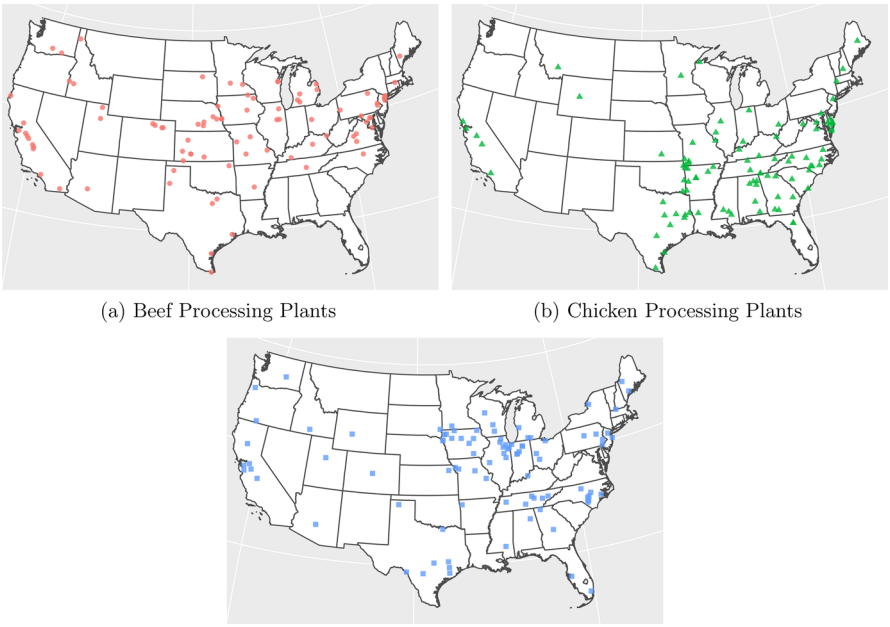
(d) Chicken (Exits)

(e) Swine (Entrants)

(f) Swine (Exits)

Fig. 5 Plant-level turnover (share of total head).*Notes:* This figure shows plant-level turnover characterized in panels **a**, **c**, and **e** as the share of total head slaughtered by new entrants in their first year of entry and in panels **b**, **d**, and **f** as the share of total head slaughtered by exiting plants in their final year of production

processing plant had a total of two competing plants that processed a total of 184.1 thousand head within a 150-mile radius. In 2021, the number of competitors within this same radius remained the same for median-sized beef plant processing facility with a total of 712.4 thousand head harvested by competitors. Of the largest 100 swine processing facilities, the median-sized plant faced 4 competitor plants in 1991



(a) Beef Processing Plants

(b) Chicken Processing Plants

(c) Swine Processing Plants

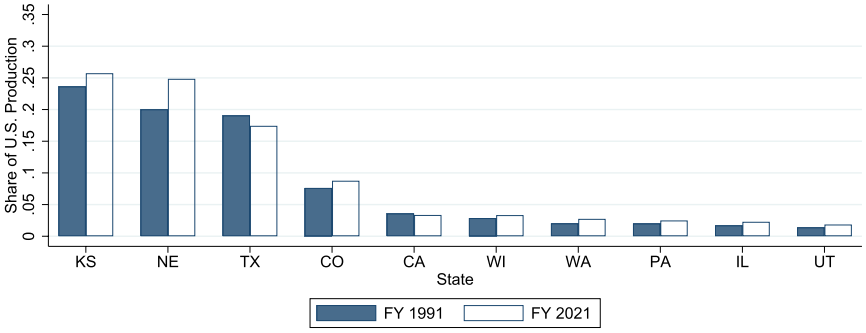
Fig. 6 Largest 100 Meatpacking Plants (2021). *Notes:* This figure shows the location of the largest 100 Federally Inspected beef, pork, and chicken processing plants. These data include kill plants (i.e., processing plants that slaughter animals) and not plants that are solely responsible for further processing

and 3.5 in 2021, but the number of head processed in competitor plants increased from 1.7 million head in 1991 to 6.4 million head in 2021.

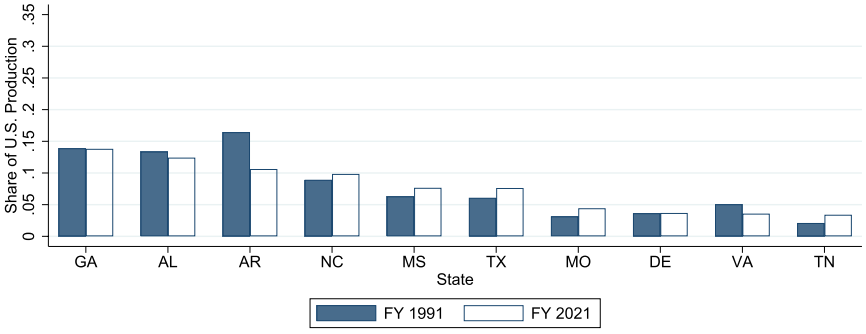
To those who are familiar with concerns that have been raised by producers with respect to having too few buyers for their livestock these results may appear counterintuitive.[19] However, Table 1 is a national summary that obscures some of the underlying variation in regional competition which is at the foundation of producers' perspectives.

Geographic concentration in beef and swine production and processing has been increasing over time (Welsh et al., 2003; Herath et al., 2005). As this has occurred, plants in the central processing regions—e.g., KS and NE for beef—have experienced increased regional competition. At the same time, regions from which processing operations have been shuttered or exited have experienced a decline in regional competition. It is in these locales where producer concern and unrest has been the most heated.

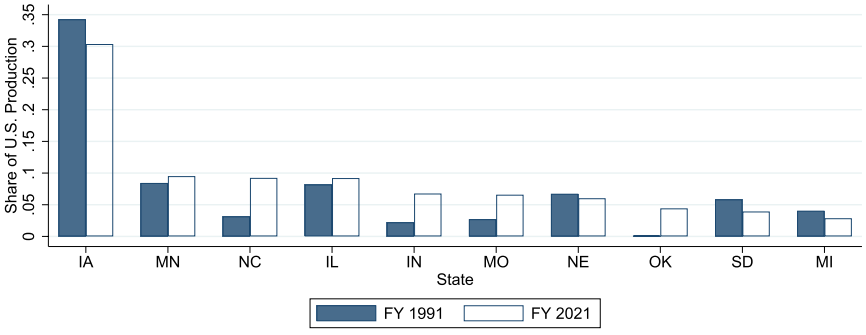
[19] During the Department of Justice's listening sessions in 2010 one cattle producer summarized what many testified to: "While potentially there are four market participants, what we see typically region by region is that there are really one to two meaningful participants, rarely three, and four meaningful participants is very much of an oddity" (U.S. Department of Justice (2010), 211:6-10).



(a) Cattle (Steer and Heifer)



(b) Chicken



(c) Swine

Fig. 7 State-level concentration. *Notes:* This figure shows beef, chicken, and swine production by state (reported as the corresponding share of total U.S. production) for fiscal years 1991 and 2021, for the top ten states as of 2021

To shed light on regional differences in spatial competition patterns, Table 2 reports the mean number of other processing plants within a 150-mile radius from a given processing plant, disaggregated by the 12 USDA NASS Regions. As with the

Table 1 Neighbor proximity (1991 versus 2021)

Species	Proximity measure	FY 1991				FY 2021			
		Mean	Median	Min	Max	Mean	Median	Min	Max
All plants									
Cattle	No. of plants	21.8	14	0	113	21.2	16	0	90
	Head (Thousands)	431.1	25.6	0	4996.7	474.3	39.1	0	7579.2
Chicken	No. of plants	8.7	6	0	33	10.2	8	0	37
	Head (Millions)	267.0	163.8	0	927.5	378.2	279.1	0	1094.4
Swine	No. of plants	21.2	16	0	99	19.7	16	0	72
	Head (Millions)	2.0	1.1	0	18.9	3.7	2.0	0	37.8
Top 100 plants									
Cattle	No. of plants	2.3	2	0	10	3.0	2	0	11
	Head (Thousands)	578.2	184.1	0	4,895.2	712.4	168.1	0	7,517.9
Chicken	No. of plants	5.8	5	0	16	5.5	5	0	13
	Head (Millions)	284.9	214.6	0	784.9	406.3	375.3	0	945.9
Swine	No. of plants	3.5	4	0	9	4.6	3.5	0	17
	Head (Millions)	3.3	1.7	0	16.9	6.4	3.2	0	31.4

This table reports mean, median, minimum, and maximum number of other processing plants and the number of total head processed within a 150-mile radius from a given processing plant. Complete spatial density estimates are shown in Appendix Figure A3

U.S.-wide analysis in Table 1, we conduct this analysis both for all plants and for a sample that is limited to the 100 largest plants for each species.

We begin with the "all plant" analysis in Table 2. In the cattle processing industry, spatial competition in the Eastern Mountain region (Kentucky, Tennessee, West Virginia, Virginia, and North Carolina) has fallen dramatically from an average of 59.9 "neighbor" processors within a 150-mile radius in 1991 to just 18.2 "neighbors" in 2021. This pattern is also true—though to a lesser extent—for the Great Lakes region (Michigan, Indiana, and Ohio), where the average number of other processing plants within a 150-mile radius has fallen from 14.5 in 1991 to 8.5 in 2021, and in the Northern Plains region (Kansas, Nebraska, South Dakota, and North Dakota), where the number of neighboring processors has fallen from 22.5 to 13.6 over the 30-year period of analysis. The "all plants" analysis in Table 2 shows similar patterns also exist for swine processing in the Northwest (Washington, Oregon, and Idaho) and Southern (Florida, Alabama, Georgia, and South Carolina) regions. In these regions, spatial competition has fallen from an average of 19.4 and 20.5 neighbors, respectively, in 1991 to just 7.9 and 11.2 neighbors in 2021.

Conclusions with regard to regional competition are similar when we limit the analysis to the largest 100 plants for each species. For example, in the Northwest U.S., a cattle plant faced an average of three other plants within a 150-mile radius in 1991. As of 2021, such a cattle plant faced less than two competing plants. Similar patterns exist for broiler and swine processing facilities in the Southern U.S. Thus, although national aggregates suggest that regional competition has intensified, there are legitimate concerns that have been expressed by producers in marginal regions

Table 2 Regional neighbor proximity (1991 versus 2021)

USDA region	Mean plant count within 150 miles						Mean head harvested (millions) within 150 miles					
	Cattle		Chicken		Swine		Cattle		Chicken		Swine	
	1991	2021	1991	2021	1991	2021	1991	2021	1991	2021	1991	2021
All plants												
Delta	10.0	9.9	8.9	7.7	3.7	13.6	0.0	0.0	286.3	286.2	0.0	2.6
Eastern mountain	59.9	18.2	8.9	13.7	22.2	49.0	0.8	1.0	326.2	653.0	4.1	2.3
Great lakes	14.5	8.5	3.7	6.8	7.8	32.3	0.0	0.4	54.3	27.3	0.6	3.9
Heartland	20.0	55.9		6.1	25.1	20.7	0.2	0.8		184.2	9.1	4.6
Mountain	8.4	8.7		1.0	11.2	7.2	0.5	0.8		0.0	3.1	0.0
Northeastern	30.7	28.4	5.2	14.6	34.0	29.4	0.4	0.2	137.8	422.4	3.2	2.5
Northern plains	22.5	13.6		3.0	20.8	25.6	1.2	1.9		38.0	4.9	4.1
Northwest	9.2	19.7	1.6	2.9	19.4	7.9	0.2	0.5	17.4	29.2	2.4	0.1
Pacific	11.7	9.4	7.7	6.2	7.8	9.9	0.2	0.2	176.1	194.5	2.0	1.1
Southern	11.7	22.0	17.5	18.3	20.5	11.2	0.1	0.2	525.3	607.7	2.5	0.7
Southern plains	7.9	13.4	8.2	10.0	5.2	6.6	0.7	0.4	313.4	441.3	2.8	1.1
Upper midwest	12.4	22.5	2.8	4.2	16.9	14.5	0.1	0.5	49.9	60.6	7.6	4.4
Sample average	21.8	21.2	8.7	10.2	21.2	19.7	0.4	0.5	267.0	378.2	2.0	3.7
Top 100 plants												
Delta			3.3	3.4		3.5			165.6	240.0		2.8
Eastern mountain	1.6	1.7	4.9	7.3	5.7	4.5	0.0	0.0	236.7	570.2	8.6	4.6
Great lakes	1.4	1.5				4.5	0.0	0.0				2.5
Heartland	4.3	4.0			9.4	5.7	0.7	0.9			11.4	5.0
Mountain	1.8	2.6			1.0		1.1	1.1			0.0	
Northeastern	3.3	6.6	6.5		2.5	3.0	0.7	0.7	303.7		1.8	1.4
Northern plains	4.7	5.0			4.5	3.2	2.0	3.3			9.1	5.2
Northwest	3.0	1.9			1.5	1.0	0.4	0.4			0.0	0.0
Pacific	2.2	4.9	1.2	1.5	4.2	4.5	0.3	0.3	126.8	133.5	3.0	1.5
Southern	1.0	6.6	8.4	5.9	4.8	2.8	0.0	0.9	410.1	441.2	0.6	0.7
Southern plains	2.4	1.6	5.0	5.3	2.4	3.0	0.5	0.2	257.3	367.8	3.2	2.7
Upper midwest	1.9	2.6			4.9	5.0	0.3	0.3			10.8	8.4
Simple average	2.3	3.0	5.8	5.5	3.5	4.6	0.6	0.7	284.9	406.3	3.3	6.3

Notes: This table reports mean number of other processing plants and mean number of head harvested in millions within a 150-mile radius from a given processing plant, disaggregated by the 12 USDA NASS Regions

where processing operation exit has left voids in procurement markets. Further, in terms of head harvested, while the national numbers indicate that plants are in proximity to greater levels of processing capacity, this differs greatly by region. For swine, nine of the 12 USDA NASS Regions reveal a decrease in average processing capacity.

6 Conclusion

Market disruptions over the last several years have reinvigorated concerns with respect to the resiliency and competitiveness of the U.S. meatpacking industry. On the heels of the COVID-19 pandemic, calls have been made to investigate the procurement practices, marketing margins, and throughput decisions that are being made by meat processors (Lusk et al., 2021; Ramsey et al., 2021). Yet, this suspicion and disquiet is not new. There have been waves of investigations and inquiries in the past. One example that is related to the trend in increasing concentration that has been observed over time is the Congressional hearings held in 1985 and 1990 that focused on cattle prices and rancher losses and precipitated a Congressionally mandated U.S. Department of Agriculture (USDA) study of potential monopolistic pricing practices and mergers and acquisitions in the meat packing industry (Nguyen & Ollinger, 2006).

The same strategy is being employed today with the USDA's investigation of meat packers' behavior during the pandemic (U.S. Department of Agriculture, 2020) and policy makers' proposing regulatory alterations to make livestock procurement more competitive and promote the entry of small- and medium- sized processing operations to enter the industry (Azzam, 2022). Yet, despite these efforts and inquiries, there has not been a comprehensive assessment of current levels of concentration and consolidation in U.S. meatpacking. Further, the analyses of concentration in the meatpacking sector have largely been national in scope.

There are meaningful consequences of concentration at a regional level that may not be detected when conducting analysis at such an aggregate (national) level. Plant-level FSIS production data can be used to fill this void, so as to make more recent and nuanced information available to underpin policy initiatives and analysis.

Our examination of the data offers the following findings. The concentration ratios indicate a steady increase in ownership concentration, consistent with the previous literature. The beef and pork sector exhibited significant plant consolidation which intensified over the past thirty years which contrast with the chicken sector that has held a more uniform distribution over time. While the largest beef and pork plants have gotten larger, the share of animals harvested at the smaller processing facilities has remained stable. For both meat and poultry sectors, turnover represents a minimal share of production with entry and exit being dominated by small fringe plants. Finally, a spatial analysis suggests that the beef and pork sectors have become slightly more geographically concentrated whereas for chicken slightly less. While spatial competition for beef and pork sectors increased in the central processing regions, secondary production regions have experienced a drop in regional competition.

In this research, we consider trends in processing facility consolidation, ownership changes, and how regional procurement markets have changed over time. But—in many ways—our analysis just scratches the surface of what is possible to do with the FSIS data. We encourage future research that extends exploration of the FSIS data to address issues of market power, consolidation, and resilience in the U.S. meatpacking sector.

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Author Contributions TS, AS and DS were responsible for data analysis and prepared the initial draft of the manuscript. All authors reviewed and commented on the manuscript and advised data analysis as necessary.

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Data Availibility The data used to conduct this analysis are not publicly available and were obtained via a cooperative work agreement with the Office of the Chief Economist. Non-Disclosure Agreements limit our ability to share information that discloses any particular company's identity. The findings and conclusions in this article are those of the authors and do represent any official U.S. Department of Agriculture or U.S. government determination or policy.

Declarations

Conflicts of Interest The authors report no conflicting interests relevant to this work.

Ethical Approval This project did not involve human subjects research.

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