Meatpacking Concentration: Implications for Supply Chain Performance

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Abstract

The meatpacking industry is a crucial intermediary between ranchers and the downstream supply chain, and concentration within the industry has significant implications for stakeholders in terms of competition and transmission of efficiencies. Due to constraints on the efficient transportation of live animals over long distances, ranchers primarily operate within regional markets. In this paper we provide new knowledge about the degree of regional concentration in the beef packing industry and propose a model to examine its impact on the wholesale farm-price spread. Findings indicate a significant increase in concentration across all regions, with some regions experiencing up to a 300 percent rise in the Herfindahl index, although concentration levels vary considerably among the different regions.

KEYWORDS: Meatpacking, Concentration, Competition, Oligopsony, Oligopoly, Cost-efficiency,

JEL Classification Q11 · C13 · L00 · L11 · L13 · L66

1. Introduction

Ranchers must transport cattle to packing plants that are, on average, about 155 miles away (BQA, 2016; USDA-APHIS-VS, 2013), which restricts ranchers' slaughter options to regional processing plants. Concentration in the midstream of a supply chain is of vital importance due to its impact on the upstream and downstream supply chain through competition, passthrough of efficiencies, and the ability to respond to unexpected external shocks. When examining concentration, however, it is crucial to account for industry-specific characteristics and potential constraints that shape the market. In the context of the beef packing industry, it becomes essential to acknowledge the constraints faced by ranchers in transporting live animals (USDA, 2022b).

The meatpacking industry in general is becoming more concentrated (Ward, 2010; Morrison Paul, 2001) due to the rapid consolidation and exit of smaller processors (MacDonald et al., 2000). The largest 3.3 percent of plants processed 70 percent of all U.S. meat (USDA, 2022b). Although larger plants and companies can result from efficiencies and economies of scale, increasing concentration raises concerns about market power on both the buying side (which affects ranchers) and on the selling side (which affects consumers).

Traditionally, two opposite effects emerge from increasing concentration in an industry: market power effects and cost-efficiency effects. Bain (1956) argued that a higher competitive intensity enables firms to raise market power, which may widen margins and facilitate collusion. Conversely, Stigler (1950) suggested that firms may effectively reduce production costs when the market becomes more concentrated. Many NEIO studios have since been conducted to understand the consequences of high concentration in the meatpacking industry. Most were performed at a national level or do not include concentration explicitly in the model (Lopez et al., 2018;

Panagiotou & Stavrakoudis, 2016; Lopez et al., 2002; Azzam, 1997; Azzam & Pagoulatos, 1990; Schroeter, 1988), and those that are at regional level are dated (Azzam & Schroeter, 1995). Furthermore, these studies usually measure oligopoly, oligopsony, and/or cost efficiencies.

High levels of concentration could create large disruptions in the supply chain when the sector is confronted by unexpected events that lead to plant shutdowns. Not surprisingly, then, the issue of the resilience of the meat supply chain has become more salient due to COVID-pandemic disruptions (Deese et al., 2021; Krumel & Goodrich, 2021; Ma & Lusk, 2021). Examples include the shutdown of a large plant in South Dakota due to a shortage of workers, which effectively decreased the national meat supply by seven percent; the hacking of the JBS food processing company this past summer; and record retail price inflation of meat products since February 2020. Previously, a small percentage of the processing capacity had been affected by accidents in some packing plants (Azzam & Dhoubhadel, 2021), but the shock created by COVID-19 was unprecedented. The pandemic has become a litmus test for the meat supply chain's resilience, revealing its vulnerability to demand and supply shocks (Lusk et al., 2021; Ma & Lusk, 2021). Lusk et al. (2021) found an unprecedented increase in the price spread, measured by farm-to-wholesale price differences, that could threaten food security in the United States. Farmers' already-declining share of retail dollars for meat decreased even more after the onset of COVID-19, as shown in Figure 1. Ma & Lusk (2021) showed that it is challenging to avoid short-run supply/demand shocks regardless of firm structure. Similarly, Azzam & P. Dhoubhadel (2021) failed to reject competitive pricing in the cattle and beef industry as one of the reasons for declining returns to farmers.

The July 9, 2021, Biden-Harris executive order to promote competition directed federal agencies, including the USDA, to review competitive conditions in the U.S. economy and, citing

increasing concentration in food retailing and in meatpacking as primary concerns, tasked the Secretary of Agriculture with seeking remedies for unfair treatment of ranchers (Deese et al., 2021; The White House, 2021). Notably, the gap between the prices received by ranchers and meat processors has widened significantly during the pandemic, resulting in low prices for farms and higher prices for consumers (see Figure 1).

There is, therefore, a renewed and critical need to better understand the evolving concentration and competition in the meat industry and the implications for processors, ranchers, and consumers. Extant studies have mostly analyzed seller concentration at the national level, while a few studies examine regional buyer power of the larger processors that ranchers must confront. This study aims to fulfill a critical need for new evidence by measuring concentration within the beef packing industry, which is a significant segment of the broader meatpacking industry, at the regional level. The contributions of the present study are twofold. First, we document the levels of industrial concentration at the regional market level. Second, we formalize a structural profit maximization model that considers regional concentration in purchasing (from ranchers) as well as national concentration in selling (to wholesalers), using price spread as an indicator of meat supply chain resilience.

The paper is organized as follows: Section II describes the data and how we use it. Section III discusses the evolution of regional concentration in the beef packing industry. Section IV formalizes the theoretical model, and Section V concludes.

2. Data

Our analysis uses data from the NETS database provided by the firms Walls & Associates and Dun and Bradstreet. NETS is a panel dataset that comprises annual observations on specific lines

of business at unique locations from 1990-2021.[1] For each establishment, it is possible to identify the industry it belongs to, gross sales (nominal dollars), employment, and location. Each establishment is assigned a unique identifier (DUNS) that makes it possible to track it over time at the 8-digit (SIC-8) Standard Industrial Classification level. [2]

We identify an establishment that belongs to the beef packing industry using the 6-digit SIC code (201101) provided by NETS. This code identifies all plants that do any cattle slaughter, even if they are primarily active in meat processing. We adjust those establishments where the 201100 SIC code provided by NETS does not allow differentiation between the specific meatpacking industries (beef, pork, and lamb). If an establishment has more than 100 employees, we will search various databases to assign it to a specific industry, while for the remaining establishments or those with more than 100 employees where individual industry identification is not possible, we will divide the sales of each establishment based on the annual per capita consumption of red meat (beef and pork) at the national level.

A key advantage of NETS is that we have available the hierarchical structure of the firms, which enables us to identify the group of business lines that belong to the same firm through the headquarters assigned to each business line. This approach also enables researchers to circumvent restrictive confidentiality rules and accurately identify specific firms.

[1] While there is no legal obligation for establishments to participate or report truthfully, D&B has strong profit-based incentives to compile accurate data, and individual businesses' access to credit and other business relationships may depend on the quality of the information they provide. (Barnatchez et al., 2017)

[2] Standard Industrial Classification (SIC) codes are four-digit numerical codes assigned by the U.S. government to business establishments to identify the primary business of the establishment. The classification was developed to facilitate the collection, presentation, and analysis of data, and to promote uniformity and comparability. The classification covers all economic activities. SIC codes have been extended to create the most accurate way to target businesses, using 6-, 7-, or 8-digit SIC Codes that break down industries even further. These are known as Extended SIC Codes.

NETS dataset contains business lines with only one employee (self-employed), a characteristic not typically accounted for in many official sources. Many business lines with one employee are non-employee business lines, i.e., they do not have paid employees. Although employment at those enterprises may at times be the result of imputations[3], Barnatchez et al. (2017) show that taking out those imputations leaves measures of regional employment that are generally highly correlated with those in the Census Bureau's County Business Patterns (CBP) across industries, mimicking the official employer dataset.

An additional difference between NETS and official sources such as the Census Bureau's County Business Patterns (CBP) and Nonemployer Statistics (NES) and the Bureau of Labor Statistics' Quarterly Census of Employment and Wages (QCEW), is that official sources record establishment existence and employment on specified, uniform dates. NETS records are annual, but information is collected throughout the year, and the timing of measurement for each establishment is not reported in the data, which could be a source of possible micro-level measurement error.

We use NETS sales to calculate the regional Herfindahl Hirschman Index (H),[4] using the 10 regions defined by USDA[5] for the beef packing industry, given by:

$$H_{t,m} = \sum_{i=1}^{N_{mt}} s_{i,m,t}^2 = \frac{1+ CV_{m,t}^2}{N_{mt}}, \quad (1)$$

[3] Direct contact with the business is an important source of D&B's employment data for these smallest establishments. If the business cannot be contacted or does not answer questions, D&B can be forced to impute missing employment values using cross-sectional information (e.g., establishment location or industry).

[4] The NETS data set has been widely used, including in studies that document industry concentration across different geographies (Rossi-Hansberg et al., 2021; Çakır et al., 2020).

[5] USDA has defined 10 different regions than contain the following states: region 1 (CT ME NH VT MA RI), region 2 (NY NJ), region 3 (DE-MD PA WV VA), region 4 (AL FL GA KY MS NC SC), region 5 (IL IN MI MN OH WI), region 6 (AR LA NM OK TX), region 7 (IA KS MO NE), region 8 (CO MT ND SD UT WY), region 9 (AZ CA HI NV) and region 10 (AK ID OR WA).

where $H_{t,m} \in [1/N_{mt}, 1]$ is the sales concentration in market m at time t, N_{mt} the number of firms in market m at time t, and $CV_{m,t}^2$ is the coefficient of variation of firm's sizes. Thus, if all firms were the same size, then $H = 1/N_{mt}$, and the more unequal the sizes (CV higher) the higher H, with larger values indicating greater concentration. According to the Department of Justice/Federal Trade Commission 2010 horizontal merger guidelines (DOJ-FTC, 2010), an H above 0.15 is considered "moderately concentrated," and an H above 0.25 is considered "highly concentrated." An ideal design would include a significant fraction of the regional markets above and below the highly concentrated 0.25 threshold.

The other measure of concentration we use throughout the study is the fraction of total sales accrued by the four largest firms in an industry (denoted as CR4), given by:

$$CR4_{t,m} = \sum_{i=1}^{4} s_{i,m,t,} \quad (2)$$

where $CR4_{t,m} \in [0, 1]$ is the sales concentration in market m at time t, and $s_{i,m,t}$ is the share of sales of the ith firm at time t in market m.

3. Evolution of Regional Market Concentration

As far back as 1888, the U.S. meatpacking industry has been associated with allegations of anticompetitive practices within cattle markets. These concerns have played a role in the enactment of various antitrust laws, notably the Sherman Antitrust Act. From 1920 through the1960s, various factors, such as reduced transportation costs, lower wages, availability of cheaper land, and the emergence of new sources of cattle feed in the western corn belt and southern plains, contributed to de-concentration in the meat packing industry (Azzam, 1998). However, in the 1970s, the industry underwent a transformation due to technological advancements, rising labor costs, and evolving specialized demands, which led to a change in the industry's dynamics, wherein carcasses

were processed by breaking, boning, cutting, and shipping them in boxes (Azzam, 1998). Consequently, a new phase of increasing concentration emerged in the meatpacking industry, which continues even now.

Although there has been extensive research on concentration in U.S. beef packing at the national level, there is a notable lack of recent studies examining the evolution of concentration at the regional level. Our analysis aims to address this gap by focusing on the regions defined by the USDA, as depicted in Figure 2.[6]

One important observation is that not all regions hold the same level of significance within the beef packing industry. As depicted in Figure 3, the primary production areas are the Mountain West and Northern Great Plains (regions 7 and 8), the South Central Great Plains (region 6), the North Central Corn Belt (region 5), and the Southeastern Atlantic (region 4). These areas mainly encompass the Great Plains, Corn Belt, and southeastern states; collectively, they accounted for approximately 80 percent of the total sales in the national beef packing industry from 1990 to 2021. MacDonald et al. (2000) noted that industry consolidation led to geographic shifts in slaughter plant locations that closely followed changes in the location of animal feeding facilities, and cattle slaughter operations relocated from the Corn Belt (Region 5) to the Great Plains (Regions 6 and 7). Figure 4 depicts the spatial distribution of beef packing plants employing over 100 individuals from 1990 to 2021. Notably, these slaughter facilities exhibit a clear trend towards local concentration around cattle feeding facilities. This strategic proximity facilitates efficient delivery for slaughter, minimizing transportation time and reducing stress on the cattle. There has also been a discernible decrease in the number of facilities with more than 100 employees, accompanied by a rise in the number of facilities under the ownership of dominant players in the industry. These

[6] Tennessee is not included in any region.

trends underscore the ongoing consolidation and market concentration within the beef packing sector.

For comparison purposes, we analyze the evolution of concentration by computing the Herfindahl index (H) and the fraction of total sales accounted for by the four largest firms in the industry (CR4). To measure changes in concentration across all regions relative to the base year of 1990, we calculate the weighted average of the concentration change (ΔH/ΔCR4):

$$\Delta Concentration_t = \sum_{m=1}^{N} S_{tm}^{R} \Delta Concentration_{tm}, \quad (3)$$

where S_{tm}^{R} denotes the sales share of the region at year t in region m over national sales in year t, and $\Delta Concentration_{tm}$ represents the regional change in H or CR4 between year t and 1990.

Similarly, to measure the level of concentration across all regions, we calculate the weighted average of the regional concentration (H/CR4):

$$Concentration_t = \sum_{m=1}^{N} S_{tm}^{R} Concentration_{tm}, \quad (4)$$

where S_{tm}^{R} denotes the sales share of the region at year t in region m over national sales in year t, and $Concentration_{tm}$ represents the regional H or CR4 for each year.

Figure 5 demonstrates a consistent pattern of increasing concentration at the regional level across all measures since 1990. The weighted Herfindahl index has experienced an approximately 80 percent rise during this period, while the weighted fraction of sales accounted for by the four largest firms has increased by around 40 percent. However, the evolution of concentration has not been uniform throughout the entire period. In fact, concentration peaked around 2000, followed by a continuous decline until 2006. From 2006 onwards, concentration began to rise again, ultimately reaching a new peak in 2021. (It is perhaps worth noting that JBS entered the U.S. meatpacking

market in 2006.) Figure 6 provides further insights into the concentration levels. The weighted regional CR4 experienced an increase of more than 15 percentage points, rising from 60 percent to over 75 percent during the period. Simultaneously, the weighted regional Herfindahl index increased significantly, reaching nearly 0.25, indicating a state of "high concentration" by the end of the period. The Herfindahl index rose from 0.10 to 0.25 during this time.

Table 1 presents the average concentration levels and their evolution for each of the 10 regions, highlighting the significant heterogeneity not only in the levels but also in the changes over time. According to the 2010 horizontal merger guidelines from the Department of Justice/Federal Trade Commission, regions 1, 8, and 10 are classified as "highly concentrated." However, it should be noted that region 8 accounts for a substantial portion of beef production. Two more regions fall into the category of "moderately concentrated" and also contribute significantly to beef production, while the remaining regions are considered to have low concentration levels. In total, five out of the ten regions exhibit moderate or high levels of concentration. On average, the regions that do not represent a significant part of total beef production have higher Herfindahl index values due to the lower presence of industries in those areas, with two of the three regions having Herfindahl index values above 0.25. Although all regions have experienced an increase in their concentration measures, such as CR4 or H, since 1990, regions 6 and 10 have more than doubled their Herfindahl index levels since 1990. Furthermore, these regions have witnessed an increase of over 50 percent in the fraction of sales accounted for by the four largest firms.

The higher levels of concentration indicate that fewer owners possess the existing establishments, with mergers and acquisitions involving the largest firms being one of the main drivers. But the push to operate larger and more efficient plants to capitalize on economies of scale alone does not explain the increase in firm size through mergers and acquisitions. There may be

advantages in procuring livestock for multiple plants (Ward, 2010), and multi-plant firms have an advantage over single-plant firms in dealing with potential food safety crises that could lead to plant closures (Janofsky, 1997; Martin, 2008). Additionally, economies of scope may play a role, as larger plants with more diversified processing operations have been found to have greater technological economies (Morrison Paul, 2001). Finally, the emergence of multi-plant coordination using computing technology in supply chain management allows for economies of scale in procurement, processing, and downstream marketing processes, thereby reducing competition among plants owned by the same firm (Pudenz & Schulz, 2023).

When examining the evolution of establishments, it becomes evident that not only do the existing establishments belong to fewer owners, as indicated by the Herfindahl index (H) or CR4, but also that the number of establishments has decreased in all regions without significant variations in intensity during the period from 1990 to 2021, as depicted in Table 2. Additionally, we observe an increase in the size of the establishments, as shown in Table 3. This trend can be attributed, at least partially, to the economies of scale in the meatpacking industry (Ward, 2010 ; Morrison Paul, 2001; MacDonald et al., 2000). Large, cost-efficient packing plants enjoy cost advantages unavailable to smaller plants, primarily due to their size and higher utilization rates. Furthermore, changes in consumption patterns, such as the steady decline of per capita beef consumption at the national level, have contributed to the consolidation of the industry by pushing out weaker or smaller businesses.

In summary, our analysis reveals an increase in concentration at the regional level across all regions. This increase is accompanied by a reduction in the total number of establishments, an expansion in the size of existing establishments, and a decrease in the number of companies operating in these markets.

4. Theoretical Analysis

Following, Azzam & P. Dhoubhadel, (2021) and Ma & Lusk, (2021), we used price spread as an indicator of meat supply chain resilience. However, unlike previous work, our equation is based on structural profit maximization, considering concentration in purchasing as well as selling.

In view of the intended application, consider an industry consisting of N firms converting a single material input into a final output. The conversion technology of each company is defined by a fixed ratio between material input and output.[7] Meatpackers manufacture products and sell them in the output market by combining slaughtered animals with other non-material inputs that are purchased in competitive markets and used in variable proportions. Profits for the *i*th firm (for i = 1; 2; . . .; N) can be expressed,

$$\pi_i = [p_w(Q^{ND}) - p_r(Q^{RS})]q_i - c_i(W)q_i - FC_i, \quad (5)$$

where p_w represents the price received from selling wholesale beef and p_r the price paid to ranchers, with a non-meat unit cost of $c_i(W)$, where W is a vector of prices' q_i indicates the quantity bought and sold by firm i, and FC_i is the fixed cost. $Q^{ND} = \sum_{i \in NA}^{N} q_i$ is the amount of beef sold by all plants at the national level (NA), assumed to be the level of meat retail competition, and $Q^{RS} = \sum_{i \in R}^{N} q_i$ is the amount processed by all plants in the same USDA region (R). Thus, while purchasing competition is affected by regional concentration, the selling price is affected by national demand factors. The impact of shocks experienced by local plants on national beef prices has recently become clear.

[7] The assumption of one-to-one fixed proportion in the technology of meatpacking is common in the literature since it is impossible to produce more meat through substitution of non-meat inputs. This assumption is appropriate if a food processing firm cannot affect the yield from the raw material (Schroeter, 1988). Analytically, this allows us to denote the raw material and output by the same variable.

Let market price and quantities be related via national demand and regional supply functions,

$$Q^{ND} = f(p_w, Z_1), \tag{6}$$

$$Q^{RS} = f(p_r, Z_2), \tag{7}$$

where p_w is the price of wholesale beef, p_r is the price of the live cattle, and Z_1 and Z_2 are vectors of exogeneous variables. The problem for the ith firm is to choose q_i to maximize equation (5) subject to (6) and (7).

Differentiating equation (5) with respect to q_i, we have the first order necessary condition of the profit maximization problem:

$$\frac{\partial \pi_i}{\partial q_i} = p_w - p_r + \frac{\partial p_w}{\partial Q^{ND}} \frac{\partial Q^{ND}}{\partial q_i} q_i - \frac{\partial p_r}{\partial Q^{RS}} \frac{\partial Q^{RS}}{\partial q_i} q_i - c_i(W), \tag{8}$$

Multiplying equation (8) by $(\frac{Q^{ND}Q^{RS}}{Q^{ND}Q^{RS}})$ yields,

$$p_w - p_r = -\frac{\partial p_w}{\partial Q^{ND}} \frac{\partial Q^{ND}}{\partial q_i} \frac{Q^{ND}Q^{RS}}{Q^{ND}Q^{RS}} q_i + \frac{\partial p_r}{\partial Q^{RS}} \frac{\partial Q^{RS}}{\partial q_i} \frac{Q^{RS}}{Q^{RS}} q_i + c_i(W), \tag{9}$$

Rearranging equation (9), we obtain,

$$p_w - p_r = -\frac{Q^{RS}}{Q^{ND}} \frac{q_i}{Q^{RS}} \left(\frac{\partial q_i}{\partial q_i} + \sum_{j \neq i \in NA}^{N} \frac{\partial q_j}{\partial q_i}\right) \frac{\partial p_w Q^{ND}}{\partial Q^{ND}} + \frac{q_i}{Q^{RS}} \left(\frac{\partial q_i}{\partial q_i} + \sum_{j \neq i \in R}^{N} \frac{\partial q_j}{\partial q_i}\right) \frac{\partial p_r Q^{RS}}{\partial Q^{RS}} + c_i(W), \tag{9a}$$

$$p_w - p_r = S^R S_i (1 + \lambda_i) \frac{1}{\eta_{ND}} + S_i (1 + \theta_i) \frac{1}{\varepsilon_{RS}} + c_i(W), \tag{9b}$$

where $p_w - p_r$ is known as the price spread as defined by the USDA. S_i denotes the share of the output of firm i in the regional market, and S^R denotes market share of the regional sales relative to national sales. λ_i and θ_i denote collusion parameters for selling and purchasing power. More

specifically, $\lambda_i = \sum_{j \neq i \in NA}^{N} \frac{\partial q_j}{\partial q_i}$ is the conjecture on how other firms at the national level react to changes in quantity processed by the *ith* firm, and $\theta_i = \sum_{i \neq 1}^{N} \frac{\partial q_j}{\partial q_i}$ is the conjecture on how other firms in the same regional market react to changes in quantity processed by the *ith* firm. The terms $\eta_{ND} = -\frac{\partial Q^{ND}}{\partial p_w} \frac{1}{Q^{ND}} (\eta_{ND} > 0)$ and $\varepsilon_{RS} = \frac{\partial Q^{RS}}{\partial p_r} \frac{1}{Q^{RS}} (\varepsilon_{RS} > 0)$ denote the absolute national demand semi-elasticity and ranchers' supply semi-elasticity, respectively, which provide bounds on the extent of market power of processors.

The firm's conjectures λ_i and θ_i can vary from -1 to 0. The market is perfectly competitive on both the buyer and seller sides, and when $\lambda_i = \theta_i = -1$ the firm expects its input/output decision to be entirely offset by the inputs/outputs of competing firms. However, $\lambda_i = \theta_i = 0$ means that the firms behave as a Cournot oligopoly, where the firm expects that its input/output adjustment cannot induce change in their competitors.

Following (Azzam, 1997), the processing cost function of the ith firm takes the form of the generalized Leontief functional form introduced by Diewert (1971):

$$c_i(W) = q_i \sum_i \sum_j \alpha_{ij} (w_i w_j)^{\frac{1}{2}} + q_i{}^2 \sum_i \beta_i w_i \,, \tag{10}$$

where $\alpha_{ij}$and β_i are parameters.

The optimizing condition (9b) becomes,

$$p_w - p_r = S^R S_i (1 + \lambda_i) \frac{1}{\eta_{ND}} + S_i (1 + \theta_i) \frac{1}{\varepsilon_{RS}} + \sum_i \sum_j \alpha_{ij} (w_i w_j)^{\frac{1}{2}} + 2 q_i \sum_i \beta_i w_i. \tag{11}$$

Weighting each firm's output q_i by the respective regional market share ($\frac{q_i}{Q^{RS}}$), and summing the equation across the N firms, the output function at regional level is derived:

$$p_s - p_b = HS^L(1 + \Theta)\left(\frac{1}{\eta_D}\right) + H(1 + \Phi)\left(\frac{1}{\varepsilon}\right) + \sum_i \sum_j \alpha_{ij}(w_i w_j)^{\frac{1}{2}} + 2HQ^{RS}\sum_i \beta_i w_i, \quad (12)$$

where $p_s - p_b$ is farm-wholesale margin. $H = \sum_{i \in R} S_i^2$ denotes the Herfindahl-Hirschman index at the regional level, and S^L denotes market share of the region's sales relative to national sales.

The terms Φ and Θ denote collusion parameters for purchasing and selling power. In practice, absence of panel data on firm-level output and employment levels of factors of production means that (12) cannot be readily estimated. This limitation leads us to consider the problem at the regional industry level. To do so, however, an additional assumption must be maintained to make the preceding analysis applicable to the behavior of the industry as whole. The assumption is that, in equilibrium, the conjectural elasticities are invariant across firms, treating Θ and Φ as constants. (Appelbaum, 1982).

According to (12), the farm-wholesale margin is composed of three elements: a market power factor on the selling side assessed by the first term, a market power factor on the buying side assessed by the second term, and a marginal processing cost component as measured by the last two terms.[8] This structure allows us to test whether all firms are price-takers in the output/input. If $\Theta = -1$ and $\Phi = -1$, the market is perfectly competitive. Conversely, if they are equal to 0, the market is a Cournot oligopoly. Other combinations of market structures can be identified: monopsony on the buying side and perfect competition on the selling side ($\Theta = 0$ and $\Phi = -1$) and vice versa. The ratios of the conjectural elasticities to the demand and supply elasticities measure the degree of market power in the output and input market, respectively.

[8] Ideally, the model should also have a derived demand equation for each of the nonmaterial inputs. Unfortunately, data for this was not available.

Differentiation of (12) with respect to the Herfindahl index yields the effect of concentration on the price spread:

$$\frac{\partial(p_s - p_b)}{\partial H} = S^L(1 + \Theta)\left(\frac{1}{\eta_D}\right) + (1 + \Phi)\left(\frac{1}{\varepsilon}\right) + 2Q^{RS}\sum_i \beta_i w_i, \quad (13)$$

where the first term is the market power effect on the selling side, the second term is the market power effect on the buying side, and the third term is the cost-efficiency effect.

Following Lopez et al. (2002), the ratio of industry marginal cost to average cost provides a measure of the cost elasticity in relation to the spread:

$$e_{cy} = \frac{MC}{AVC} = \frac{A + 2HQ^{RS}B}{A + HQ^{RS}B}$$

where $A = \sum_i \sum_j \alpha_{ij}(w_i w_j)^{\frac{1}{2}}$ and $B = \sum_i \beta_i w_i$. Note that e_{cy} represents economies of size and is the inverse of the degree of returns to scale. If B equals zero, it indicates constant returns, and the impact of increased concentration on spreads is due to oligopoly or oligopsony power. If B is greater than zero, it suggests diseconomies of scale and increasing concentration that leads to higher prices resulting from increased oligopoly and oligopsony power and costs. In cases where economies of scale are present (B is less than zero), the effect of concentration on prices can be positive, negative, or zero, depending on whether the impact of oligopoly and oligopsony power is greater than, smaller than, or equal to the effect of cost efficiency.[9]

5. Conclusions

[9] Note that these effects of concentration are applicable when the level of output remains constant. In the case of increasing returns to scale, higher concentration results in lower costs. Conversely, for decreasing returns to scale, higher concentration leads to higher costs. If there are constant returns to scale, concentration does not bring about any change in costs. When output is fixed, an increase in the Herfindahl index implies a shift in output distribution among firms, with larger firms producing a greater share of output, thereby reducing industry costs in the presence of economies of scale.

Our results show a clear trend towards heightened concentration within all regions at the regional level. This upward shift in concentration is paralleled by a notable decline in the overall count of establishments, as well as a noteworthy expansion in the size of the existing establishments. Moreover, there has been a noticeable decrease in the number of companies actively participating in these markets. These combined factors underscore the ongoing consolidation within the industry, indicating a significant shift towards larger, more dominant players operating in the regional beef packing sector.

We intend to further explore the implications of market concentration in the beef packing industry by employing the model outlined in this paper. Through our analysis, we aim to quantify the precise impact of this concentration on the farm-wholesale price spread. By delving into this aspect, we seek to gain a deeper understanding of how the increased concentration within beef packing markets influences the pricing dynamics between farmers and wholesalers. By shedding light on these relationships, we hope to contribute insights to the ongoing discourse surrounding market concentration and its effects on various stakeholders within the beef industry.

References

Appelbaum, E. (1982). The estimation of the degree of oligopoly power. *Journal of Econometrics*, *19*(2), 287–299. https://doi.org/10.1016/0304-4076(82)90006-9

Azzam, A. M. (1997). Measuring market power and cost-efficiency effects of industrial concentration. *The Journal of Industrial Economics*, *45*(4), 377–386. https://doi.org/10.1111/1467-6451.00054

Azzam, A. M. (1998). Competition in the US meatpacking industry: Is it history? *Agricultural Economics*, *18*(2), 107–126. https://doi.org/10.1111/j.1574-0862.1998.tb00492.

Azzam, & P. Dhoubhadel. (2021). *COVID-19, Beef Price Spreads, and Market Power*. https://doi.org/10.22004/AG.ECON.313309

Azzam, A. M., & Pagoulatos, E. (1990). Testing oligopolistic and oligopsonistic behaviour: An application to the US meat-packing industry. *Journal of Agricultural Economics*, *41*(3), 362–370. https://doi.org/10.1111/j.1477-9552.1990.tb00652.x

Azzam, A. M., & Schroeter, J. R. (1995). The tradeoff between oligopsony power and cost efficiency in horizontal consolidation: An example from beef packing. *American Journal of Agricultural Economics*, *77*(4), 825–836. https://doi.org/10.2307/1243806

Bain, J. S. (1956). Advantages of the large firm: Production, distribution, and sales promotion. *Journal of Marketing*, *20*(4), 336–346. https://doi.org/10.1177/002224295602000402

Barnatchez, K., Crane, L. D., & Decker, R. A. (2017). An assessment of the National Establishment Time Series (NETS) Database. *Finance and Economics Discussion Series*, *2017*(110). https://doi.org/10.17016/FEDS.2017.110

BQA. (2016). *Beef Quality Assurance—BQA - 2016 National Beef Quality Audit*. Beef Quality Assurance - BQA. https://www.bqa.org/resources/national-beef-quality-audits/2016-national-beef-quality-audit

Çakır, M., Kong, X., Cho, C., & Stevens, A. (2020). Rural food retailing and independent grocery retailer exits. *American Journal of Agricultural Economics*, *102*(5), 1352–1367. https://doi.org/10.1111/ajae.12131

Deese, B., Fazili, S., & Ramamurti, B. (2021). *Addressing Concentration in the Meat-Processing Industry to Lower Food Prices for American Families*. The White House Briefing Room, https://www.whitehouse.gov/briefing-room/blog/2021/09/08/addressing-concentration-in-the-meat-processing-industry-to-lower-food-prices-for-american-families/

Diewert, W. E. (1971). An application of the Shephard duality theorem: A generalized Leontief production function. *Journal of Political Economy*, *79*(3), 481–507.

DOJ-FTC. (2010). Horizontal merger guidelines. U.S. Department of Justice and the Federal Trade Commission. https://www.justice.gov/sites/default/files/atr/legacy/2010/08/19/hmg-2010.pdf

Janofsky, M. (1997, August 22). 25 Million Pounds of Beef Is Recalled. The New York Times. https://www.nytimes.com/1997/08/22/us/25-million-pounds-of-beef-is-recalled.html

Krumel, Thomas & Goodrich, Corey. (2021). Meatpacking Working Conditions and the Spread of COVID-19. USDA ERS Administrative Publication No. (AP-092). https://www.ers.usda.gov/publications/pub-details/?pubid=102205#:~:text=It%20compares%20working%20conditions%20within,before%20mitigation%20measures%20were%20implemented.

Lopez, R. A., Azzam, A. M., & Lirón-España, C. (2002). Market power and/or efficiency: A structural approach. Review of Industrial Organization, 20(2), 115–126. https://doi.org/10.1023/A:1013867114881

Lopez, R. A., He, X., & Azzam, A. (2018). Stochastic frontier estimation of market power in the food industries. Journal of Agricultural Economics, 69(1), 3–17. https://doi.org/10.1111/1477-9552.12219

Lusk, J. L., Tonsor, G. T., & Schulz, L. L. (2021). Beef and pork marketing margins and price spreads during COVID-19. Applied Economic Perspectives and Policy, 43(1), 4–23. https://doi.org/10.1002/aepp.13101

Ma, M., & Lusk, J. L. (2021). Concentration and Resilience in the U.S. Meat Supply Chains). National Bureau of Economic Research, Working Paper No. 29103. https://doi.org/10.3386/w29103

MacDonald, J. M., Ollinger, M., Nelson, K. E., & Handy, C. R., Eds. (2000). Consolidation in U.S. meatpacking. Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 785.https://doi.org/10.22004/ag.econ.34021

Martin, A. (2008, February 18). Largest Recall of Ground Beef Is Ordered. The New York Times. https://www.nytimes.com/2008/02/18/business/18recall.html

Panagiotou, D., & Stavrakoudis, A. (2016). A stochastic production frontier estimator of the degree of oligopsony power in the U.S. cattle industry. Journal of Industry, Competition and Trade, 17(1), 121–133. https://doi.org/10.1007/s10842-016-0233-0

Morrison Paul, C. J., (2001). Cost economies and market power: The case of the U.S. meat packing industry. Review of Economics and Statistics, 83(3), 531–540. https://doi.org/10.1162/00346530152480171

Pudenz, C. C., & Schulz, L. L. (2023). Multi-plant coordination in the U.S. beef packing industry. American Journal of Agricultural Economics.12391. https://doi.org/10.1111/ajae.12391

Rossi-Hansberg, E., Sarte, P.-D., & Trachter, N. (2021). Diverging Trends in National and Local Concentration. NBER Working Paper, No. 25066. DOI 10.3386/w25066

Schroeter, J. R. (1988). Estimating the degree of market power in the beef packing industry. The Review of Economics and Statistics, 70(1), 158. https://doi.org/10.2307/1928165

Stigler, G. J. (1950). Monopoly and oligopoly by merger. The American Economic Review, 40(2), 23–34.

The White House. (2021, July 9). Executive Order on Promoting Competition in the American Economy. The White House. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/07/09/executive-order-on-promoting-competition-in-the-american-economy/

USDA. (2022a). Livestock Slaughter 2019 Summary. U.S. Department of Agriculture. https://downloads.usda.library.cornell.edu/usda-esmis/files/r207tp32d/34850245n/5712mr72x/lsan0420.pdf

USDA. (2022b). Packers and Stockyards Annual Reports. USDA Agricultural Marketing Service. https://www.ams.usda.gov/reports/psd-annual-reports

USDA. (2022c). USDA ERS - Meat Price Spreads. https://www.ers.usda.gov/data-products/meat-price-spreads

USDA-APHIS-VS. (2013). NAHMS Feedlot 2011. Department of Agriculture. Animal and Plant Health Inspection Service, Veterinary Services. https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-andsurveillance/nahms/NAHMS_Feedlot_Studies

Ward, C. (2010). Assessing competition in the U.S. beef packing industry. Choices, 25, 2, 15.

Table 1: Average H and CR4 Level and Change since 1990 at the Regional Level

	Average level H [(1)]	Change H 1990 - 2021	Average level CR4 [(1)]	Change CR4 1990 - 2021
Region 1 (CT ME NH VT MA RI)	0.35	55.47%	85.54%	31.07%
Region 2 (NY NJ)	0.10	72.59%	51.42%	20.88%
Region 3 (DE-MD PA WV VA)	0.19	22.93%	73.25%	16.87%
Region 4 (AL FL GA KY MS NC SC) *Southeastern*	0.11	86.29%	53.95%	35.56%
Region 5 (IL IN MI MN OH WI) *Corn belt*	0.11	83.88%	56.02%	34.70%
Region 6 (AR LA NM OK TX) *Great plains*	0.22	205.01%	74.37%	53.59%
Region 7 (IA KS MO NE) *Great plains*	0.14	35.90%	63.87%	23.18%
Region 8 (CO MT ND SD UT WY) *Great plains*	0.35	42.37%	89.51%	27.53%
Region 9 (AZ CA HI NV)	0.13	10.08%	55.75%	22.14%
Region 10 (AK ID OR WA)	0.27	281.59%	81.27%	61.45%
National level [(2)]	0.18	82.55%	67.30%	33.56%

Notes: Source NETS dataset (2021). (1) Average H and CR4 during the period 1990-2021. (2) National-level figures are derived as a weighted average of the regional Herfindahl (H) or Concentration Ratio 4 (CR4), with the weights determined by the sales share of each region in relation to the national sales.

Table 2: Evolution of the Number of Establishments

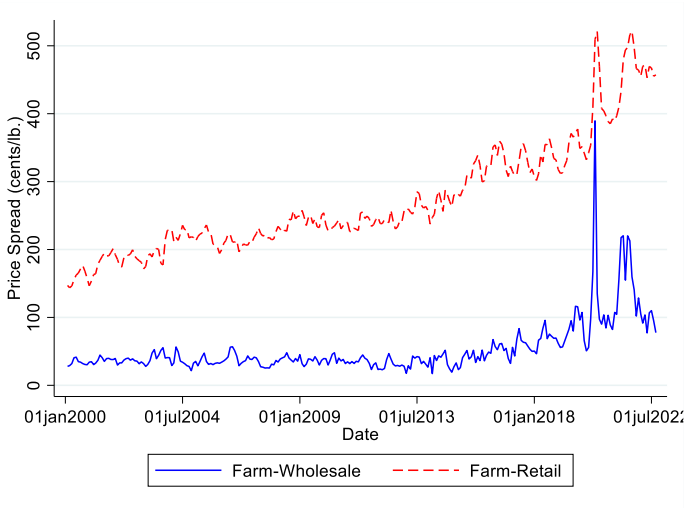
	Average number establishments [(1)]	Change number of establishments 1990-2021
Region 1 (CT ME NH VT MA RI)	35	-43.64%
Region 2 (NY NJ)	88	-42.98%
Region 3 (DE-MD PA WV VA)	152	-25.15%
Region 4 (AL FL GA KY MS NC SC) *Southeastern*	317	-41.58%
Region 5 (IL IN MI MN OH WI) *Corn belt*	383	-29.98%
Region 6 (AR LA NM OK TX) *Great plains*	287	-42.40%
Region 7 (IA KS MO NE) *Great plains*	306	-20.80%
Region 8 (CO MT ND SD UT WY) *Great plains*	203	-34.13%
Region 9 (AZ CA HI NV)	136	-37.20%
Region 10 (AK ID OR WA)	106	-51.66%
National level [(2)]	2013	-35.35%

Notes: Source NETS dataset (2021). (2) National-level figures are calculated by considering the entire United States as a single market.

Table 3: Size distribution of beef packing establishments [(1)]

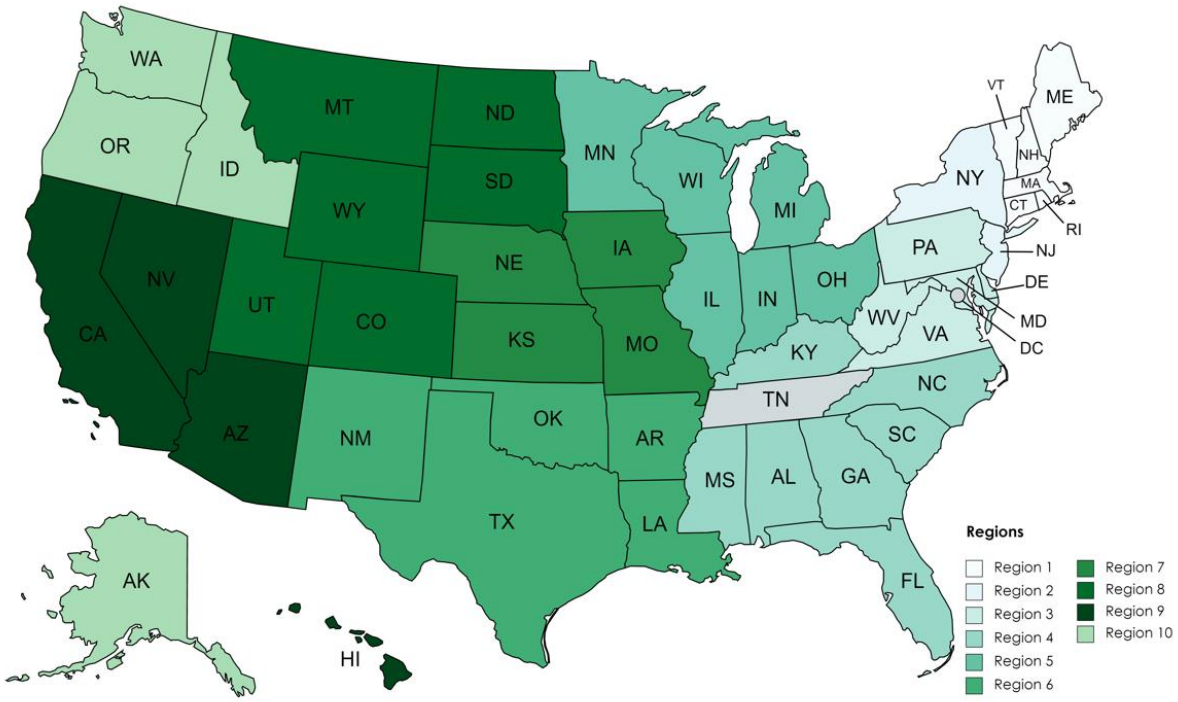
Size group (Sales Millions $)	1990		2000		2010		2021	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
0 to 0.5	23	2.53%	12	1.65%	13	2.07%	9	1.46%
0.5 to 1	41	4.51%	21	2.88%	20	3.18%	21	3.41%
1 to 5	282	31.02%	256	35.12%	225	35.83%	210	34.09%
5 to 10	137	15.07%	92	12.62%	84	13.38%	84	13.64%
10 to 100	331	36.41%	254	34.84%	219	34.87%	224	36.36%
100 to 500	89	9.79%	84	11.52%	56	8.92%	60	9.74%
500 to 750	6	0.66%	9	1.23%	10	1.59%	5	0.81%
+1000	0	0.00%	1	0.14%	1	0.16%	3	0.49%
All	**909**		**729**		**628**		**616**	

Notes: Source NETS dataset (2021). (1) Business lines with more than 10 employees



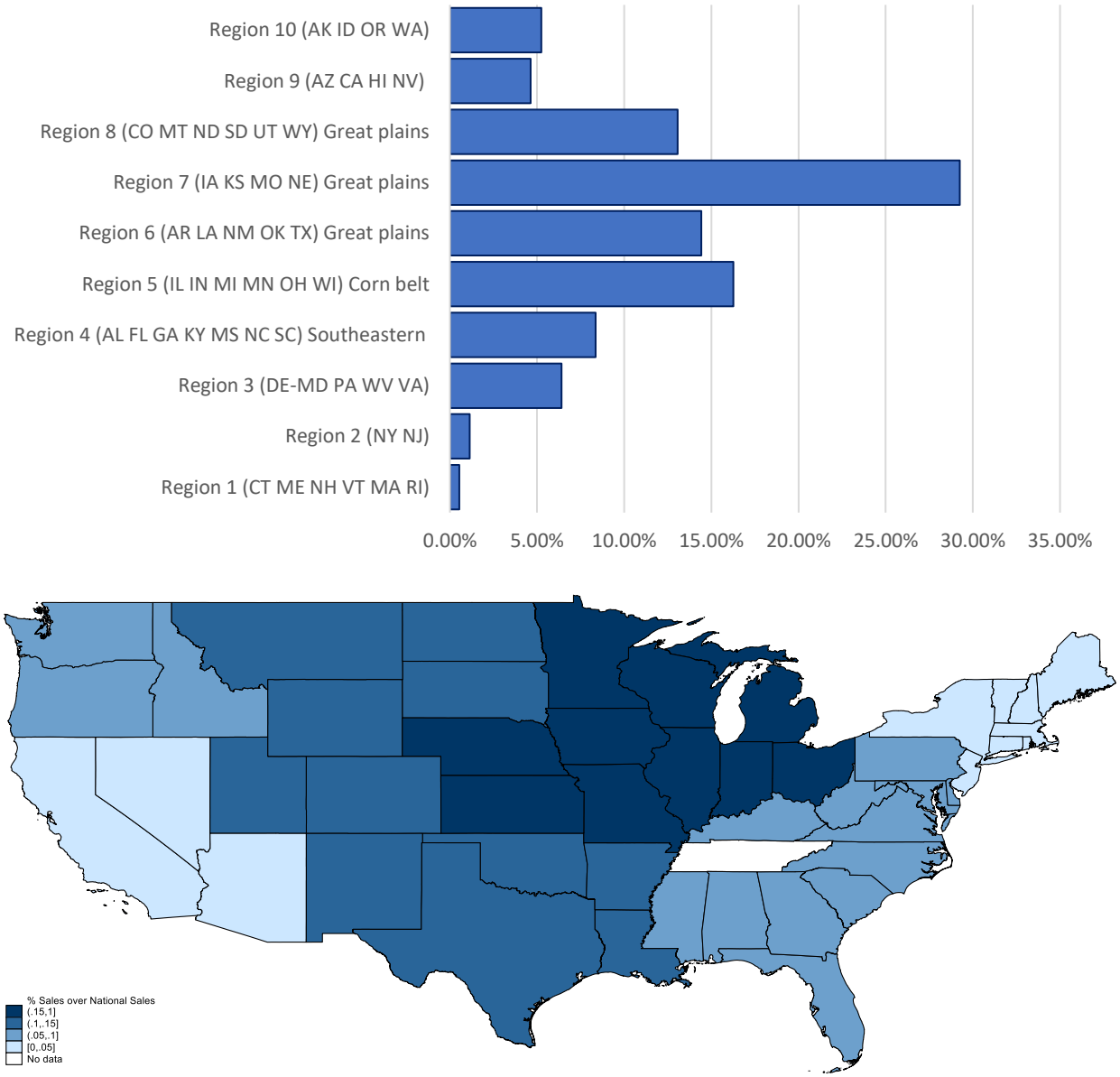
Source: USDA (USDA, 2022c)

Figure 1: National trend in the wholesale and retail farm price spread for beef.



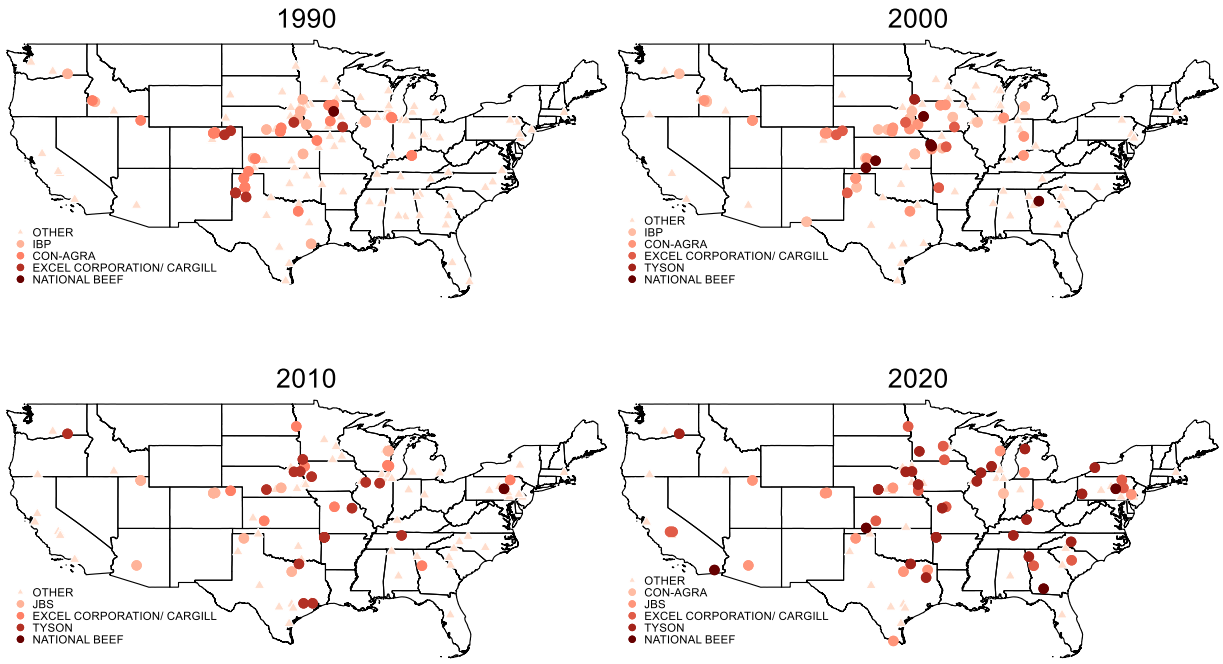
Notes: Own source based on USDA definitions: region 1 (CT ME NH VT MA RI), region 2 (NY NJ), region 3 (DE-MD PA WV VA), region 4 (AL FL GA KY MS NC SC), region 5 (IL IN MI MN OH WI), region 6 (AR LA NM OK TX), region 7 (IA KS MO NE), region 8 (CO MT ND SD UT WY), region 9 (AZ CA HI NV) and region 10 (AK ID OR WA)

Figure 2: Regions defined by USDA



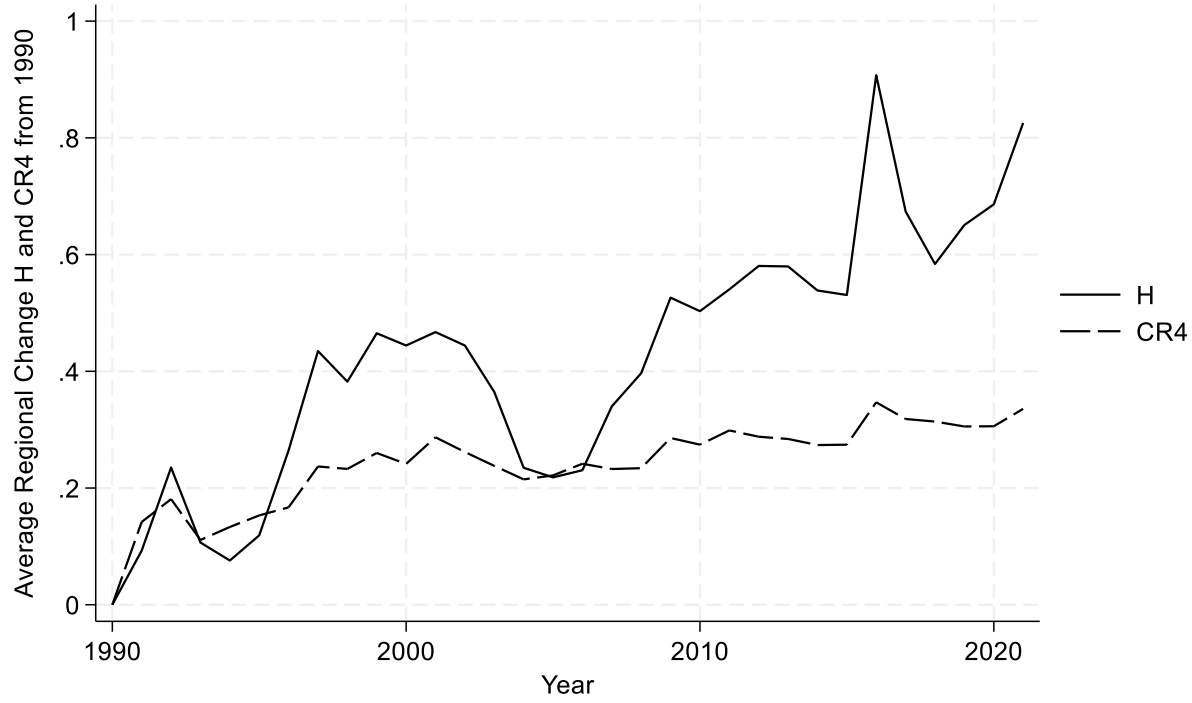
Notes: Source NETS dataset (2021). Represent the average percentage sales of the U.S region over the total sales of the beef packing industry (SIC 201101) during the period 1990-2021.

Figure 3: Average percentage sales period 1990-2021 by region.



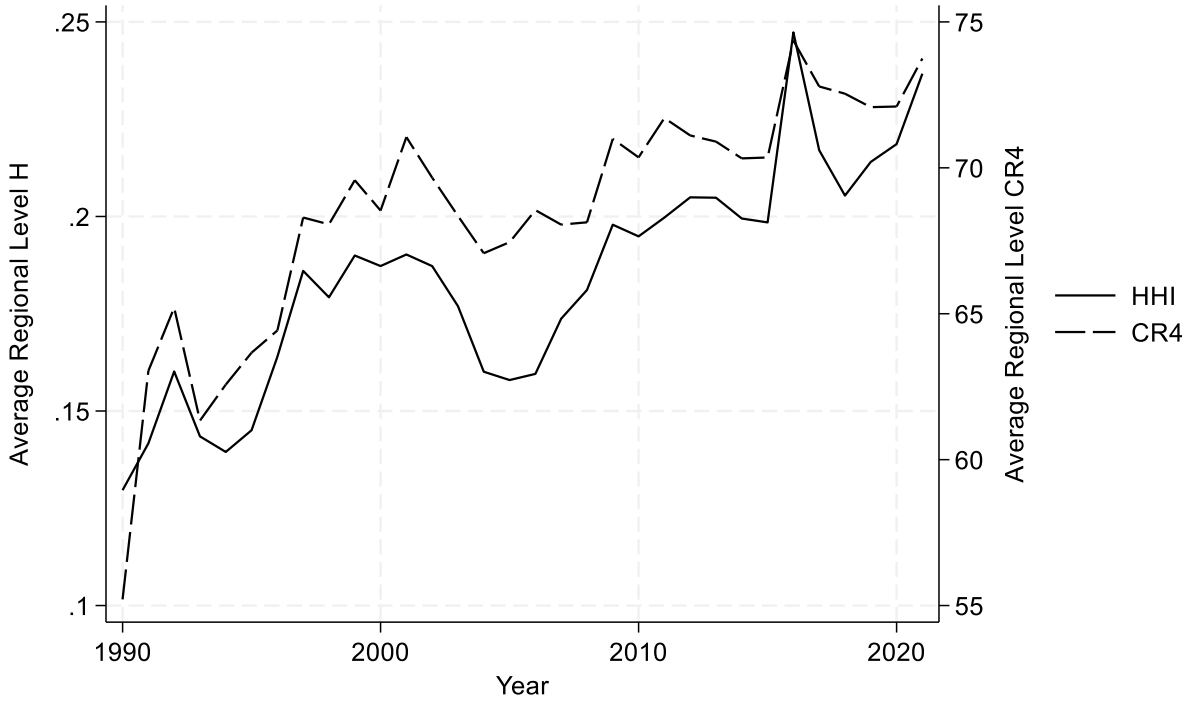
Notes: Beef packing plants (SIC 201101) by firm (color) with more than 100 employees. Source NETS dataset (2021)

Figure 4: Fed cattle beef packing plants by firm 1990-2021



Notes: Source NETS dataset (2021)

Figure 5: Average regional change H and CR4 from 1990



Notes: Source NETS dataset (2021)

Figure 6: Average regional level H and CR4 from 1990