Market Manipulation by a Monopsony Cartel: Evidence from the U.S. Meatpacking Industry

Jingyi Huang *

July 21, 2024

Abstract

If a monopsony cartel manipulates market signals used by small sellers, it can result in a larger welfare loss than standard models predict. This paper examines the U.S. meatpacking cartel's impact on the cattle market between 1903 and 1917, a period during which government litigation forced the cartel to cease manipulating market prices. I quantify the welfare effects by comparing observed market outcomes under manipulation with counterfactual measures under standard monopsony. The findings suggest that transitioning from manipulation to monopsony would benefit cattle sellers by increasing wholesale cattle prices by 30.4 percent. This coincides with a minimal decrease in consumer welfare, with the average household spending $1.93 more per year on beef.

JEL Classifications: D22, L13, L66, N61, N82

Key Words: monopsony, cartel, market manipulation, meatpacking

*Brandeis University, Department of Economics. Email: jingyi.huang.econ@gmail.com. I am grateful to my advisers John Asker, Dora Costa, Michela Giorcelli, and Nico Voigtländer for their advice and support throughout this project. I thank Simon Board, Martin Hackmann, Hugo Hopenhayn, Michael Rubens, and seminar participants at UCLA, UC Berkeley, Northwestern, Harvard, Yale, NBER Summer Institute, Lund FRESH, MaCCI, EHS, IIOC, EARIE, and audiences at various conferences and workshops for comments and suggestions. I also thank Mary Yeager and Louis Cain for helpful discussions on the archival materials. The UCLA Center for Economic History provided financial support for data collection.

1 Introduction

Can a monopsony cartel cause larger welfare loss by manipulating the market signals used by small sellers? While both antitrust agencies and empirical research call for more attention to the adverse effects of monopsony, economic theory provides a limited understanding of monopsonistic cartel strategies.[1] Contrary to the assumptions of the standard monopsony model, cartel buyers often possess more private information regarding market conditions than small sellers. When sellers make production or shipping choices, they rely on market signals that can be manipulated by the price-setting cartel. Without accounting for the impact of signal manipulation, the standard monopsony model may underestimate the welfare loss caused by a cartel.

This paper examines the impact of signal manipulation by the U.S. meatpacking cartel on both the input market (cattle) and the product market (beef). In the early 20th century, five meatpackers formed one of the largest manufacturing cartels in American history. The cartel dominated wholesale cattle and beef markets, purchasing 95 percent of the cattle sold at the 10 largest stockyards and producing more than 80 percent of refrigerated beef for urban markets. During an era of weak antitrust enforcement, they openly colluded to manipulate the wholesale cattle market from 1893 to 1920 (Yeager, 1981).

Two factors make this historical case particularly suitable for examining the effect of a cartel manipulation strategy. First, because the cartel was eventually challenged in court, the resulting litigation generated detailed documentation on how the cartel manipulated market prices. For example, the court found that cartel members were guilty of "bidding up through their agents, the prices of livestock for a few days at a time, to induce large shipments, and then ceasing from bids, to obtain livestock thus shipped at prices much less than it would bring in the regular way."[2] Second, in 1913, cartel members stopped manipulating prices in exchange for the Department of Justice to drop pending cases. However, this did not dissolve the cartel, as it switched to a standard monopsony strategy with fixed market shares. As a result, I observe market outcomes under both the manipulation and monopsony strategies, allowing me to compare empirical outcomes under cartel manipulation to counterfactual measures based on the well-understood monopsony model.

I first characterize the cartel's manipulation strategy using a simple two-period game with asymmetric information. Every period, the cartel observes the demand states (for beef), which are correlated over time. Cattle sellers are rational. They do not observe the demand state but can imperfectly infer it from observed cartel prices and quantities. By offering a higher first-period

[1] The Department of Justice challenged a merger on the grounds of increasing monopsony power in grain trade (Cargill and Continental Grain Company, 1999), health insurance (Anthem and Cigna, 2016), and book publishing (Penguin Random House and Simon & Schuster, 2022). It has also brought enforcement against firms abusing monopsony power in labor market (*United States v. Hee et al.*, 2022). In January 2022, the Federal Trade Commission (FTC) and the Department of Justice announced that they would broaden the scope of merger guidelines to address the potential impact of monopsony power ("Request for Information on Merger Enforcement"), 2022. For empirical analyses of monopsony power, see Berger, Herkenhoff, and Mongey (2022), Krueger and Ashenfelter (2022), Dube, Jacobs, Naidu, and Suri (2020), Ashenfelter, Farber, and Ransom (2010), and Manning (2003) on labor markets; Inderst and Mazzarotto (2008) on retail distribution; Rubens (2023) and Chatterjee (2023) on agricultural products, and Hemphill and Rose (2018) and Werden (2007) on antitrust enforcement.

[2] *Swift & Co. v. United States* (122 F. 529)

price, the cartel can shift sellers' beliefs about the high demand state. This induces more sellers to arrive at the market in the second period, thereby increasing the cartel's profit in the second period. Thus, the cartel can receive higher total profits compared to the standard monopsony model, despite deviating from the optimal price strategy in the first period.

I compile a novel data set that consists of weekly market data from 1903 to 1917. These data were obtained from several primary sources that include annual reports of stockyard companies and merchant exchanges, as well as two livestock trade journals, *The National Provisioner* and *The Drover's Journal*. The main variables of interest are the quantities of cattle arrived at stockyard markets, the quantities purchased by the cartel, and the cartel's prices. The data cover the four largest stockyards, which collectively produced more than 58 percent of U.S. refrigerated beef during the study period.

I start the empirical analysis by providing descriptive evidence on how cartel manipulation affected the wholesale cattle market. I first find that manipulation led to different aggregate market outcomes: under manipulation, the cartel purchased 40.4 percent more cattle, yet the wholesale price was 4.4 percent lower. These lower prices reduced sellers' margin—defined as the difference between wholesale cattle price and input (corn and hay) prices—by 24.1 percent. Though the reduced-form results are consistent with the narrative evidence, they provide limited information on counterfactual market outcomes absent of manipulation. This limitation requires a structural model to capture the cartel's strategies and sellers' responses.

In the second part of the analysis, I estimate the stockyard cattle supply using data after 1913, when the cartel followed the monopsony strategy. I use a discrete choice model (Berry, 1994): at stockyard markets, cattle sellers choose between the cartel and the outside competitive market. To address price endogeneity, I use prices of beef substitutes in the urban market (e.g., chicken) as an instrumental variable (IV) to estimate the spot-market cattle supply. The estimation suggests that the cartel held substantial market power over sellers, who received 60.3 percent of marginal revenue products.

I then use the estimated model primitives to quantify the effects of cartel manipulation on both the input and product markets. I consider two counterfactual scenarios—monopsony and symmetric oligopsony—and find three sets of results. First, in the wholesale cattle market, cartel manipulation causes more damage to small sellers than what the standard monopsony benchmark suggests. Without the manipulation, the average wholesale cattle price would increase by 30.4 percent, and the average total quantity purchased by the cartel would decrease by 19.7 percent, or about 15,000 fewer heads of cattle processed per week. Second, for urban consumers, the manipulation strategy created a small benefit by increasing the beef supply. However, the effects are much smaller: without cartel manipulation, higher wholesale beef prices would increase total household expenditure on beef by $1.93 annually. Finally, while disrupting the manipulation recovered some welfare loss, the improvement is relatively small compared to the case when the cartel would be dissolved. Under the oligopsony scenario, 21,500 more heads of cattle would be process per week, while the wholesale cattle price would almost double the average price under manipulation.

This paper contributes to three strands of existing literature. First, it builds on empirical research examining the inner workings of cartels. Past research uses court filings and internal documents to analyze how cartel members communicate and coordinate market strategies (Byrne and De Roos, 2019; Harrington and Skrzypacz, 2011; Levenstein and Suslow, 2006). A related literature focuses on specific cartel strategies across different markets and regulatory environments (Byrne et al., 2023; Asker and Hemphill, 2020; Marshall and Marx, 2012; Röller and Steen, 2006; Genesove and Mullin, 2001). This paper uses a historical case to highlight that the cartel can use a more complicated strategy to manipulate market signals. The results highlight that the standard monopsony benchmark may underestimate the welfare loss, especially in the input market.

Second, this paper relates to the literature on the rise of industrial cartels and antitrust regulations in the early 20th century. The meatpacking cartel was one of the largest manufacturing cartels in U.S. history and was among the first to be challenged in court (Lamoreaux, 2019). Prior research has detailed the cartel's development (Chandler, 1993; Libecap, 1992; Lamoreaux, 1988) and how competition policies evolved in response to the new market structure (Lamoreaux, 2023; Aduddell and Cain, 1981). More broadly, recent empirical studies have used historical cases to understand the effects of market structure and firm strategies (Donna and Espín-Sánchez, 2023; Delabastita and Rubens, 2023). This paper contributes to the historical analyses by documenting and quantifying the effect of a specific cartel strategy. In addition, while previous research examines how firms adapt to new regulations, this paper focuses on how the cartel responded to antitrust agencies' enforcement choices. The empirical results show that, without going through a lengthy legal process to fully dissolve a cartel, antitrust agencies can recover a non-trivial amount of cartel damage to small sellers by disrupting the manipulation strategy.

Finally, a growing literature on buyer power and imperfect competition in the agricultural markets finds that dominant buyers negatively affect input prices (Chatterjee, 2023; Rubens, 2023; Garrido, Kim, Miller, and Weinberg, 2022). Recent research from legal and antitrust policy perspectives also call for more attention to the adverse effects of monopsony on both sellers and overall market efficiency (Blair and Harrison, 2010; Hemphill and Rose, 2018; Werden, 2007). By quantifying the cartel's effects on both the input and product markets, the results show that substantial welfare loss to small sellers can be recovered at little cost to downstream consumers. The results echo other works that highlight the limitation of focusing on consumer welfare when analyzing buyer power in input markets.

2 Historical Background of the Meatpacking Cartel

In this section, I offer some historical background on the meatpacking industry and the government litigation against the cartel. I follow the convention in historical texts and use "meatpackers", "packers", and "cartel members" interchangeably.

2.1 Meatpacking Industry in the Early 20th Century

In the 1880s, Midwestern meatpackers adopted mechanical refrigeration, creating the modern meatpacking industry (Anderson, 1953). Instead of shipping live cattle to Eastern markets, packers could only ship the carcasses in tightly packed ice-refrigerated rail cars. While these rail cars substantially reduced the shipping cost of beef,[3] the fixed cost of constructing specialized rail cars, ice plants, and refrigerated warehouses along the transportation lines created high barriers to entry.[4] By the early 20th century, five firms (the "Big Five") dominated the meatpacking industry.

In the cattle market, the Big Five were the dominant buyers. For example, in 1916, they slaughtered 6.5 million cattle, accounting for 82.2 percent of all wholesale refrigerated beef sold in interstate commerce (Federal Trade Commission, 1919). Refrigerated beef production was highly concentrated both across and within stockyard markets: the 10 largest stockyard markets contributed to almost 80 percent of all cattle slaughtered for interstate trade. Chicago Union Stockyard alone processed nearly 25 percent of all the refrigerated beef. Within each market, the Big Five purchased almost all cattle sold at the stockyards (see Appendix Table 1). Because they dominated the purchase of cattle and refrigerated beef production, they naturally dominated the downstream wholesale beef market. By 1903, they furnished 75 percent of all beef consumed in New York City, 85 percent in Boston, 60 percent in Philadelphia, and 95 percent in Providence (Bureau of Corporations, 1905).

It is worth noting that there was a large competitive outside market for live cattle. In 1909, slaughtering and meatpacking establishments processed 59.6 percent of all cattle slaughtered for food in the United States,[5] while the rest were processed on farms or in retail slaughterhouses. Despite the cartel dominating urban markets, less than half of the U.S. population lived in urban areas in the 1910s. Residents in small towns and rural areas created a competitive market for live cattle, giving sellers the option to either sell to the cartel at the stockyards or to small retail butchers in this competitive market.

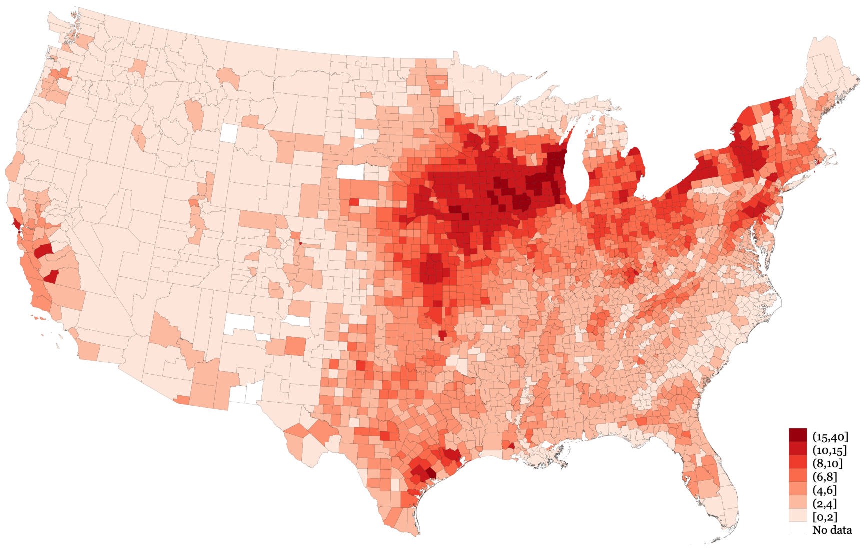
2.2 Cattle Production and the Stockyard Market

In the early 20th century, cattle production was concentrated in the Midwest. Figure 1 displays the spatial distribution of cattle in 1910, with Illinois, Wisconsin, Iowa, and Kansas having the highest cattle density. Small feedlot farmers fatten cattle for three to six months using corn and hay, before shipping to the market. About 85 percent of cattle shipped to the Chicago stockyard were fattened in this region (Clemen, 1923).

Stockyard markets consisted of a large number of price-taking cattle sellers and the monopsonistic cartel buyer. For example, the Chicago Union Stock Yards received more than 9,000 cattle per day, on average. Cattle sellers faced high shipping costs if they chose to ship to the stockyard

[3] Cattle carcasses could be shipped for one-third the cost of shipping live cattle (Bureau of Animal Industry, 1884; Skaggs, 1986).
[4] Appendix Figure 3 shows the specialized rail cars and ice manufacturing facilities along the rail lines.
[5] Value is calculated from the 1909 Census of Manufactures and the 1909 Census of Agriculture.

Figure 1: Spatial Distribution of Cattle



Notes: The map plots the average cattle density (heads per 100 acres) in 1910. Cattle production data are plotted with 1910 county boundaries and come from the 1910 Census of Agriculture (Haines et al., 2018). Values exclude milk cows and working oxen.

market. For instance, in 1908, it cost between $4.43 and $8.03 to ship a head of cattle from a feedlot in Kansas to Chicago (Andrews, 1908).[6] For comparison, the average profit per head was $29.37 for the same year (Skinner, 1909). Once the seller arrived at the stockyard market, if they were not satisfied with the cartel's price, they could leave and sell to small retail butchers in the competitive market. On average, 36 percent of the cattle shipped to the stockyards left for the outside market instead of selling to the cartel.[7]

Cattle sellers had long complained about the large supply and price variations at stockyard markets. For example, the National Live Stock Association president highlighted the frustration against the cartel at the association's 1909 annual convention: "In the past we have witnessed many violent fluctuations in the value of live stock [...] the centralization of the meat packing industry in a few hands at those large markets has mainly been responsible for the uncertain and sudden changes in prices" (American National Live Stock Association, 1909). Nevertheless, without the cattle futures market, which did not begin trading on the Chicago Mercantile Exchange until 1964, cattle sellers lacked the financial tools necessary to hedge against price fluctuations.

Stockyard markets were also conducive to collusion among meatpackers, who purchased cattle in the open market and immediately moved them to their packing plants adjacent to the stockyard for processing (see Appendix Figure 5 and Appendix Figure 6). Because the quantities and prices set by other firms were visible, cartel members could monitor compliance with their collusive agreements

[6] This cost covers the freight ($0.25–$0.55 per 100 pounds) as well as providing feed along the route, driving the cattle from the feedlot, and loading them onto rail cars (Andrews, 1908).

[7] Appendix 2 plots the distribution of the share of cattle in stockyards purchased by the cartel.

at little cost.

2.3 Refrigerated Beef Production

Cattle were slaughtered and processed into large wholesale pieces, primarily by low-skilled manual labor (see Appendix Figure 4), and there was little productivity difference across firms as they drew from the same local labor market. The main variable cost of refrigerated beef production was the cost of live cattle; labor and other variable costs were low. According to the 1909 Census of Manufactures, wages and salaries accounted for only 5.4 percent of total production cost in the slaughtering and meatpacking sector, while non-fuel materials, primarily livestock, accounted for 90.7 percent. In addition, labor was a perfect complement to the material input (cattle). Workers never secured a contract with fixed work hours and instead received hourly wages to "work until the day's killing is done" (Commons, 1904).

3 Cartel History and Strategy

Between 1893 and 1918, the cartel controlled both the live cattle market and the wholesale beef market. However, in 1913, government litigation forced the cartel to switch from a manipulation strategy to a standard monopsony strategy. Therefore, I divide the cartel strategy into two phases, before and after 1913.

Before 1913: Cartel Manipulation. In 1893, the Big Five formed a joint holding company in Chicago as a legal cover, meeting "every Tuesday afternoon at 2 o'clock" under the guise of a board meeting to blatantly collude and discuss strategies for manipulating market signals (Federal Trade Commission, 1919).[8] Circuit Judge Peter Grosscup best summarizes the strategies when granting the injunction against the packers in 1903 (*Swift & Co. v. United States* 122 F 529.):

> That the defendants are engaged in an unlawful combination and conspiracy under the Sherman Act in (a) directing and requiring their purchasing agents at the markets where the livestock was customarily purchased, to refrain from bidding against each other when making such purchases; (b) bidding up through their agents, the prices of livestock for a few days at a time, to induce large shipments, and then ceasing from bids, to obtain livestock thus shipped at prices much less than it would bring in the regular way; (c) in agreeing at meetings between them upon prices to be adopted by all, and restriction upon the quantities of meat shipped.

In 1905, in a unanimous decision, the U.S. Supreme Court upheld the lower court's ruling in the aforementioned case, affirming the injunction against the meatpackers (*Swift & Co. v. United*

[8]The three largest packers—Armour, Swift, and Morris—led every meeting. The other two smaller firms—Cudahy and Wilson—"occasionally were represented at these meetings" (Federal Trade Commission, 1919).

States, 196 U.S. 375).[9] In the majority opinion, Justice Oliver Wendell Holmes similarly summarized the cartel's manipulation strategy:

> For the same purposes [to restrain competition], the defendants combine to bid up, through their agents, the prices of livestock for a few days at a time, so that the market reports will show prices much higher than the state of the trade will warrant, thereby inducing stock owners in other States to make large shipments to the stockyards, to their disadvantage.

Though the government brought a series of high-profile cases against the cartel for antitrust violations, early legal actions had little impact.[10] The District Court for the Southern District of Illinois granted top executives immunity from criminal charges,[11] and the Department of Justice eventually dropped its case against the cartel in 1906 after the court refused to admit key evidence collected without a subpoena.[12]

In addition, while the court issued and upheld injunctions against the cartel's collusion, both the lower court and the Supreme Court's decisions included specific qualifications that "nothing herein shall be construed to prohibit the said defendants [...] from curtailing the quantity of meats shipped to a given market[...]."[13] The restrictive nature of the injunctions, together with the failed attempts to bring criminal cases against the cartel, provided no explicit threat to its continued operation. Cartel members continued to meet every week to discuss market strategies despite repeated legal challenges.

After 1913: Standard Monopsony. The Department of Justice brought a new criminal case against the packers, which went to trial in December 1911. Evidence admitted by the court included minutes of the weekly meetings showing the presence and participation of cartel executives as well as weekly telegraphs summarizing shipments and prices for every meeting.[14] However, the jury found the cartel not guilty of violating the criminal section of the Sherman Act. During deliberation, the jurors "did not review the exhibits," claiming that "the mass of figures and reports mystified them. To have attempted to untangle them would have been useless, it was agreed."[15] The consensus among historians was that the jurors were reluctant to impose criminal penalties on the prominent defendants, especially when there were no precedents against similar cartel executives in the oil and tobacco industry (Lamoreaux, 2019).

Though the executives were eventually acquitted of the criminal charges, given the abundant

---

[9] Henry Moody, the Attorney General who successfully argued this case against the cartel at the Supreme Court, became Associate Justice of the Supreme Court in 1906. It was generally believed that Roosevelt nominated Moody partly for his strong antitrust stance (Hall et al., 2005).

[10] Appendix A provides a chronicle of the government's litigation against the cartel.

[11] *The New York Times*, March 21, 1906, "Big Packers Go Free; Judge Humphrey Upholds Immunity Plea for Individuals".

[12] Witnesses gave testimonies describing the collusion to investigators from the Bureau of Corporation. District Judge Otis T. Humphrey held that such information could not be used in the criminal case (Yeager, 1981).

[13] Injunction issued by Judge Grosscup, reprinted in *Swift & Co. v. United States*, 196 U.S. 375.

[14] *The National Provisioner*, March 9, 1912, "Government Closes Case Against Packers"

[15] *The New York Times*, March 27, 1912. "Packers Acquitted; Provisions Go Up."

evidence presented in court, "the proof was so strong and so conclusive that the packers did not wish to run the risk of another trial" for a civil case.[16] Shortly after the packers were acquitted, the Department of Justice announced that it would file a civil case against them unless they dissolved the holding company where they meet as "board members."[17] The packers quickly acquiesced and agreed to submit a dissolution plan to the Department of Justice,[18] and by the end of January 1913, they finalized the dissolution and suspended their weekly meetings.

After January 1913, the cartel members resorted to the standard monopsony strategy in the wholesale cattle market: they maintained fixed market shares and collectively purchased at the same monopsony price level. The market share in the livestock purchase market was established during the holding company's dissolution in 1913. Later investigations by the FTC uncovered private meeting notes kept by a cartel member, which contained specific percentage values that each member could purchase at the livestock market.[19] To implement the market share agreement, the packers used a centralized system. All purchase decisions were made from the Chicago headquarters, which maintained regular communication with each market through private telegraph lines. At each stockyard, the packers had designated staff to record the number of livestock arriving and report this information back to headquarters. The packers' agents received orders directly from the headquarters regarding the offer price and purchase quantity. During an interview with the FTC, a buyer stated, "We are not allowed to buy more than instructed to buy. I was never allowed to go over my order, not even 25 cattle" (Federal Trade Commission, 1919).

Cartel Members Did Not Deviate. One obvious concern is that without the weekly meeting, cartel members might have deviated from the market share agreement. Past research shows that cartels may have used frequent meetings to resolve other disagreements among members (Genesove and Mullin, 2001). Suspending the weekly meetings may have led to potential deviations from the collusive agreement, which would not have conformed to the standard monopsony model.

However, due to low monitoring costs, deviation from the market share agreement is not a major concern. As discussed in Section 2.2, cartel members' packing plants were located next to each other near the stockyard, and they could directly observe every firm's realized quantity and prices. Thus, even without the weekly meeting, the stockyard environment made it difficult for them to secretly deviate from the collusive agreement.

Later investigations by the FTC uncovered evidence on cartel enforcement. Internal documents from packers for 1916 and 1917 showed that they collected weekly reports of "cattle purchases at a number of markets [...] which enables each to check the other's observance of the [market share] agreement." As a result, "each of the big packers maintains his relative percentage in the purchase

[16] *The New York Times*, June 17, 1912, "Packers to Dissolve Trust Voluntarily; Wickersham Withhold Civil Suit Pending Action by the National Packing Co."

[17] *The New York Times*, May 6, 1912. "Civil Suit Against Packers: Government to File Bill Unless Company Voluntarily Dissolve."

[18] *The New York Times*, July 20, 1912, "Meat Packers' Trust Has Been Dissolved. Division Ordered in Effort to Forestall Federal Action"

[19] The notes was under the title "Meeting held with Armour at his office, January 29th, 1913, 3:15 p.m.". See Federal Trade Commission (1919), volume 2, chapter 2.

Figure 2: Aggregate Market Share for Each Cartel Member

Notes: The graph plots the market share of each cartel member as a percentage of total cartel purchases. Market share is defined as the total quantity of cattle purchased by a particular packer across all four stockyards (Chicago, Kansas City, St. Louis, and Omaha), as a percentage of the total purchase of all packers across all four stockyards.

of live stock at the different markets fairly constantly even from week to week, more constantly from month to month, and almost exactly from year to year" (Federal Trade Commission, 1919).

In addition, public data provide empirical support for this claim. Figure 2 shows the aggregate market share for each cartel member after 1913. Relative market share among the cartel members remained stable, suggesting they did not deviate from their collusive market share agreement after suspending the weekly meetings. Note that they colluded in *all* stockyard markets to maintain constant relative market share in total quantity purchased. However, due to limited data availability, I only calculate the relative market share using the quantity from the top four stockyards, which can explain some week-to-week variations.

4 Conceptual Framework

In this section, I use a two-period model to demonstrate the intuition for the cartel's manipulation strategy. The stockyard market is characterized by a dynamic game with asymmetric information. The cartel observes the demand states, which are correlated over time. Sellers do not directly observe the demand state but can (imperfectly) infer some information about it through observed cartel prices. By manipulating market prices, the cartel can induce rational sellers to update their posterior beliefs about the state and attract more sellers to the market. Its profit increases in the number of cattle shipped to the stockyard, which in turn depends on the realized cartel prices. While it is costly to lie and deviate from the monopsony price, the cartel can potentially receive higher total profit if it sufficiently attracts more sellers who otherwise would not come to the market.

The intuition behind the cartel strategy is similar to dynamic oligopoly games with asymmetric information. For example, in Mailath (1989) and Mester (1992), firms have private information about their costs. Each firm can observe market prices and infer other firms' cost types. In such cases, firms have incentive to manipulate other market participants' beliefs through pricing.

4.1 Setup and Timeline

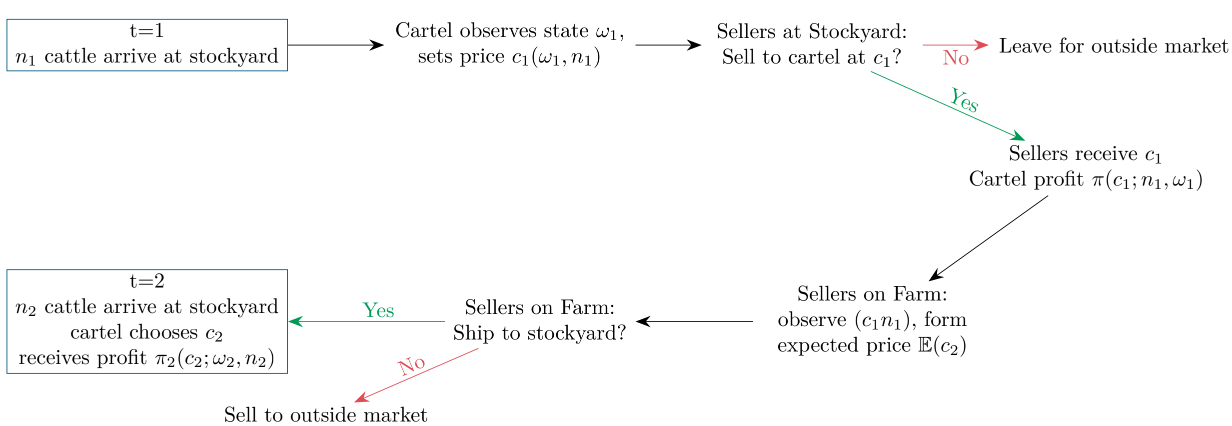
The market operates for two periods. Each seller has one unit of cattle. Cattle are identical, but sellers differ in their shipping cost θ to the stockyard. They can either sell to the competitive market with no cost (i.e., sell to local butchers) or ship cattle to the stockyard. Every period, the cartel observes the state of beef demand $\omega \in \{H, L\}$ in downstream urban markets. The demand states are correlated over time. Let $\rho(\omega_{t+1}|\omega_t)$ denote the transition probability. Sellers do not observe the state but share a common prior.

At time $t = 1$, n_1 unit of cattle arrive at the stockyard. The cartel chooses a price strategy $c_1(\omega_1, n_1)$ given the demand state and the total number of cattle that arrived. For sellers at the stockyard, the shipping costs are sunk. They observe the cartel's price and can either sell to the cartel or leave and sell to the competitive market.

Before making the shipment decision for $t = 2$, sellers on the farm observe the stockyard outcomes, (n_1, c_1), update their beliefs about the state, and form an expected cartel price for the next period. They will ship to the stockyard if the expected cartel price net of shipping cost is higher than the competitive market price.

At $t = 2$, n_2 units of cattle arrive at the stockyard, the cartel reveals the price, c_2, and sellers choose whether to accept the cartel price or leave. The game ends after the second period, as summarized in Figure 3.

Figure 3: Model Timeline



Sellers' Choices. First, consider sellers on the farm. Normalize the competitive market price to 0. A seller with cost type θ would ship to the stockyard if he expects the cartel price net of shipping cost to be higher than the competitive market price, or

$$\mathbb{E}[c_2] - \theta \geq 0. \tag{1}$$

Sellers form beliefs about $\mathbb{E}[c_2]$ after observing the market outcomes, (n_1, c_1), in the first period. Let $\mu(\omega_1|n_1, c_1)$ denote sellers' posterior beliefs about ω_1. The expected cartel price for the next period is

$$\mathbb{E}[c_2(\omega_2, n_2)] = \sum_{\omega_2} \sum_{\omega_1} \mu(\omega_1|n_1, c_1)\rho(\omega_2|\omega_1)c(n_2, \omega_2). \tag{2}$$

Equation (2) shows that sellers account for changes in aggregate supply, which affect the cartel prices. Let $F(.)$ denote the density of shipping cost θ and $\bar{N}$ denote the total number of cattle available for sale. In equilibrium, n_2 is determined by

$$n_2 = F(\mathbb{E}[c_2(n_2, \omega_2)]) \times \bar{N}. \tag{3}$$

For sellers at the stockyard, the shipping costs are sunk. They choose between selling to the cartel or to the competitive market. The indirect utility of seller i selling to $j \in \{cartel, competitive\}$ is

$$u_{it} = \begin{cases} \gamma_c c_t + \epsilon_{i,cartel} & \text{sell to cartel} \\ \epsilon_{i,competitive} & \text{sell to competitive,} \end{cases} \tag{4}$$

where the mean utility from selling to the competitive market is normalized to 0 and c_t is the cartel price. ϵ_{ij} are unobserved iid idiosyncratic preferences of seller i for buyer j, which follows a type-I extreme value distribution. The quantity of cattle the cartel can acquire at the monopsony price c_t is therefore

$$q_t(c_t|n_t) = \frac{\exp(\gamma_c c_t)}{1 + \exp(\gamma_c c_t)} \times n_t. \tag{5}$$

Note that because n_t, the number of cattle that arrived at the stockyard, shifts the spot-market supply curve out, the cartel price decreases in the total number of cattle arriving at the stockyard.

Equilibrium. The Bayesian Nash equilibrium includes the cartel's price functions, (c_1, c_2), and sellers' choices on the farm and at the stockyard such that

(1) sellers' shipment and sales decisions are optimal, given by equations (1) and (4);

(2) sellers' posterior beliefs $\mu(.)$ follow Bayes' rule and align with the cartel's strategy; and

(3) (c_1, c_2) maximize the (undiscounted) sum of expected profits:

$$\sum_{t=1,2} \mathbb{E}[\pi_t] = \pi_1(c_1; \omega_1, n_1) + \sum_{\omega_2} \rho(\omega_2|\omega_1)\pi_2(c_2; \omega_2, n_2), \tag{6}$$

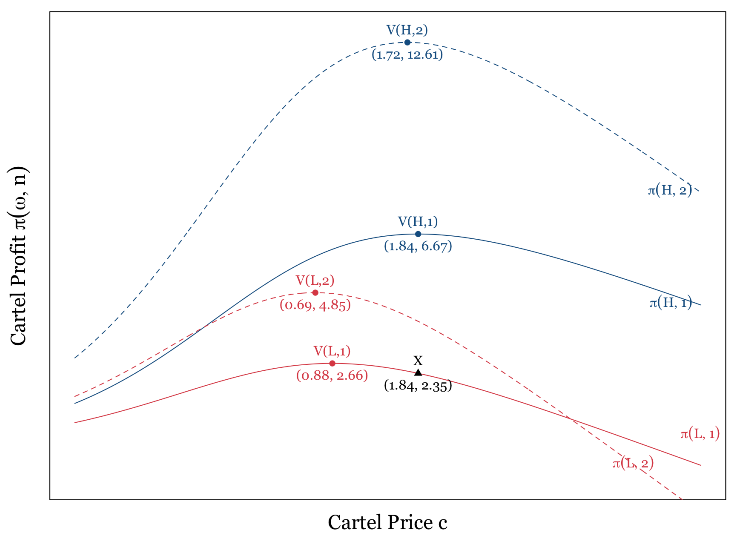
where n_2 is determined by sellers' beliefs and optimal shipment decisions, as in equation (5).

4.2 Stylized Example.

Backward induction can be used to solve for the equilibrium cartel prices in the two-stage model. Consider the following example. The cartel faces a linear inverse demand $D(q) = \omega - \frac{1}{2}q$, with $H = 10$ and $L = 5$. $\gamma_c = 1$ for the stockyard market logit supply defined in equation (5). In the first period, the cartel observes $n_1 = 1$ and $\omega_1 = L$. Sellers do not know the realized state but share the common prior that ω_1 is drawn with $\Pr(H) = 0.3$ and $\Pr(L) = 0.7$. The transition probabilities in the second period are $\rho(\omega'|\omega) = 0.7$ for $\omega' = \omega$ and 0.3 otherwise. In the second period, there are two potential sellers, one located at $\theta = 0$ and another at $\theta = 1$.

Figure 4 plots the cartel profit, $\pi(c; \omega, n)$, against the cartel prices, c, for each state-shipment combination. The solid lines represent the cartel profit when $n = 1$ seller arrives at the stockyard, while the dashed lines represent the cartel profit when $n = 2$ sellers arrive. $V(\omega, n)$ are the maximum per-period monopsony outcomes, which are labeled by the optimal monopsony price, $c^n_\omega = \arg\max \pi(c; \omega, n)$, and the corresponding profits.

Figure 4: Stylized Example



Notes: The lines represent the cartel profits for each (ω, n) pair. The profit functions are calculated given the inverse demand $D(q) = \omega - \frac{1}{2}q$, with $H = 10, L = 5$, and stockyard logit supply $q(c, n) = \frac{\exp(c)}{1+\exp(c)} \times n$. $V(\omega, n)$ denote the maximum per-period monopsony profit. Point X represents the manipulation outcome when the cartel pays the optimal H state price c^1_H even when the actual state is L.

Second Period. In the second period, the cartel faces a standard monopsony problem. After observing demand state ω_2 and total supply n_2, it will choose the monopsony prices and receive $V(\omega_2, n_2)$. Given the transition probability and that $\omega_1 = L$, the cartel's expected profit from $t = 2$ is

$$\mathbb{E}(\pi_2) = 0.3V(H, n_2) + 0.7V(L, n_2). \tag{7}$$

Note that the monopsony profit increases in n, the total number of sellers arriving at the stockyard. Therefore, the cartel has an incentive to manipulate the signal in the first period to induce a higher n_2 for the second period.

First Period. At $t = 1$, the cartel observes $\omega_1 = L$ and $n_1 = 1$.

(1) *Without Manipulation*: The cartel follows the monopsony pricing strategy in the first period, choosing c_L^1 and receiving $V(L, 1)$.

Sellers can correctly infer the state $\omega_1 = L$ after observing $c_1 = c(L, n_1)$. Given the transition probabilities, the expected price for the second period is

$$\begin{aligned} \mathbb{E}[c_2(n_2, 1)] &= 0.3c(H, 1) + 0.7c(L, 1) = 1.17 > 0, & \theta &= 0 \text{ will ship} \\ \mathbb{E}[c_2(n_2, 2)] &= 0.3c(H, 2) + 0.7c(L, 2) = 0.99 < 1, & \theta &= 1 \text{ not ship.} \end{aligned}$$

Only type $\theta = 0$ ships to the stockyard and receives the cartel price of \$1.17 in expectation. The expected cartel quantity in the second period is

$$\mathbb{E}[q_2^{\text{truth}}] = 0.3q(c_H^1, 1) + 0.7q(c_L^1, 1) = 0.75.$$

The total cartel profit is

$$\sum_{t=1,2} \mathbb{E}[\pi_t^{\text{truth}}] = V(L, 1) + 0.3V(H, 1) + 0.7V(L, 1) = 6.5.$$

(2) *With Manipulation*: If the cartel manipulates the price in the first period by pretending to be in the H state, it needs to pay a higher price, c_H^1. This leads to a lower profit in the first period, represented by point X in Figure 4.

Suppose the cartel manipulates the prices with the following probability:

$$\begin{cases} \Pr(c_H^1 | \omega_1 = H) = 1 \\ \Pr(c_L^1 | \omega_1 = H) = 0 \end{cases} \qquad \begin{cases} \Pr(c_H^1 | \omega_1 = L) = \dfrac{3}{7} \\ \Pr(c_L^1 | \omega_1 = L) = \dfrac{4}{7} \end{cases} \tag{8}$$

In other words, the cartel is honest in the H state but lies and pays c_H^1 instead of c_L^1 with probability 3/7 in the L state.

Knowing that the cartel may lie, sellers cannot be sure about current state after observing a high price in the first period. Instead, they will update their Bayesian posterior beliefs about the current state to be $\mu(\omega_1 = H|c^H) = \mu(\omega_1 = L|c^H) = 0.5$. This leads sellers to assign a higher probability on the H state in the second period, with $\Pr(\omega_2 = H) = 0.5$, instead of 0.3 when the cartel was telling the truth. The expected market price in the second period, given the posterior belief μ, is

$$\mathbb{E}_\mu(c_2^{\text{mani}}, n_2) = 0.5c(H, n_2) + 0.5c(L, n_2).$$

Prediction 1. Under cartel manipulation, more cattle will be shipped to the stockyard market.

The higher posterior belief on the H state in the second period leads to a higher expected price. Specifically,

$$\begin{aligned} \mathbb{E}_\mu(c_2^{\text{mani}}, 1) &= 0.5c(H, n_2) + 0.5c(L, n_2) = 1.36 > 0 && \theta = 0 \text{ will ship} \\ \mathbb{E}_\mu(c_2^{\text{mani}}, 2) &= 0.5c(H, n_2) + 0.5c(L, n_2) = 1.21 > 1 && \theta = 1 \text{ will ship.} \end{aligned}$$

Because both sellers will ship to the stockyard, $n_2 = 2$. This increases the cartel's profit in the second period under both states, which are represented by the dashed lines in Figure 4. The cartel's total profit under manipulation is

$$\sum_{t=1,2} \mathbb{E}[\pi_t^{\text{mani}}] = \pi(c_H^1, L, 1) + 0.3V(H, 2) + 0.7V(L, 2) = 9.5 > \sum_{t=1,2} \mathbb{E}[\pi_t^{\text{truth}}].$$

Thus, the cartel can achieve higher profits by manipulating the market price signals. While it is costly for the cartel to deviate from the monopsony price to signal a higher demand state, the additional profit generated by higher total shipment in the next period more than compensates the loss from lying about the state. The manipulation can be successful even when sellers are rational.

Prediction 2. Under manipulation, the cartel purchases more cattle at the stockyard market.

In the first period, the cartel purchased more cattle by paying a higher (manipulated) price. Consider the second period. With manipulation,

$$\mathbb{E}[q_2^{\text{mani}}] = 0.3q(c_H^2, 2) + 0.7q(c_L^2, 2) = 1.44 > \mathbb{E}[q_2^{\text{truth}}].$$

Prediction 3. Under manipulation, sellers are worse off.

The cartel manipulated sellers to assign a higher probability for the H state. As a result, while sellers *believe* the expected stockyard price to be $\mathbb{E}_\mu(c_2, 2) = 1.21$ when making their shipment decision, they will actually receive \$0.99 at the stockyard, or

$$\mathbb{E}(c_2, 2) = 0.3c(H, 2) + 0.7c(L, 2) = 0.99 < \mathbb{E}_\mu(c_2, 2).$$

In comparison, without price manipulation, the stockyard price is $\mathbb{E}(c_2, 1) = 1.17$ in the second period, higher than in the manipulation case.

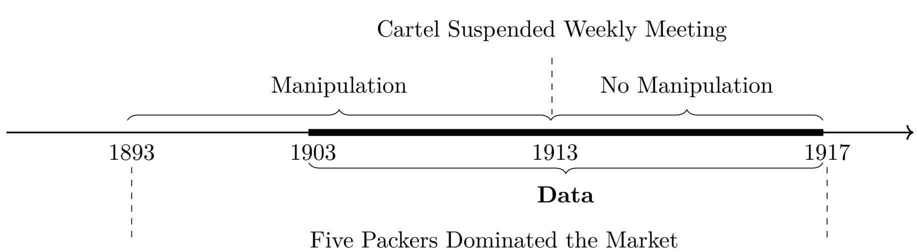
Discussion. The stylized model supports the claims documented in the legal cases that the cartel can manipulate the price signals of the wholesale cattle market to take advantage of small sellers. However, the model cannot be directly estimated due to data limitation. Specifically, estimating sellers' shipment decisions requires observing the total number of cattle available for sale and the distribution of shipping costs. It also requires strong assumptions on the distribution of demand states. Neither were directly observed and may vary over time.

Because the cartel changed its strategy in 1913, I can instead observe the market outcomes with and without manipulation. This allows me to construct the counterfactual outcomes for the manipulation period and to compare observed market outcomes with the model baseline. The result quantifies the empirical damage created by cartel manipulation while allowing for imperfect collusion or non-optimal strategies (i.e., allows the cartel to deviate from the model optimal due to unobserved institutional frictions). The drawback of this approach is that the counterfactual results are of a partial equilibrium nature: they do not account for changes in total supply to stockyards or aggregate cattle production.

5 Data

To quantify the impact of cartel manipulation on the stockyard market, I collect weekly livestock market data from historical trade journals and stockyard annual reports. These data cover the four largest stockyards from 1903 to 1917. Figure 5 shows where the data lie on the overall time frame. I combine the livestock market data with data on cattle production costs and urban wholesale market prices to analyze the decisions of both the cattle sellers and the cartel.

Figure 5: Event Timeline and Data Coverage



5.1 Livestock Market Data

I compile weekly price and quantity data from 1903 to 1917 for the four largest stockyards: Chicago, Kansas City, Omaha, and St. Louis. These markets collectively processed more than 53 percent of cattle slaughtered for interstate trade in 1916 (Federal Trade Commission, 1919).[20]

Market information—including the number of cattle shipped into the stockyards, the number of cattle purchased by the cartel, and market prices—were widely published. I collect weekly data on price and quantity from two trade journals, *The National Provisioner* and *The Drover's Journal*. I also digitize official annual reports from the Chicago Union Stockyard Company, the Chicago Board of Trade, and the Merchants' Exchange of St. Louis. For the analysis, the sample excludes observations with less than three days of trading data reported for the week, which usually occurred when stockyards were temporarily closed due to disease quarantine or extreme weather.[21]

Table 1 summarizes the stockyard market data. On average, more than 9,000 head of cattle were shipped to Chicago's Union Stock Yards every day, 60 percent of which were purchased by the cartel, with transactions valued at $1 million. The other three stockyards operated on a smaller scale but were all dominated by the cartel.[22]

Table 1: Summary Statistics

	(1) Chicago	(2) Kansas City	(3) Omaha	(4) St. Louis	(5) Total
Cattle Price ($1920)	16.92	16.45	16.36	15.89	16.40
	(2.72)	(2.65)	(2.48)	(2.82)	(2.71)
Daily Average Shipment (000s)	9.53	6.63	3.44	3.98	6.07
	(2.24)	(2.82)	(1.31)	(1.55)	(3.22)
Daily Average Cartel Purchase (000s)	5.54	4.61	2.50	2.55	3.87
	(1.54)	(3.85)	(1.55)	(1.04)	(2.59)

Note: The table show average prices and quantities for the four stockyard markets. Standard deviations are in parentheses. See Appendix B for data sources.

The spot-market prices across different markets were correlated due to two contributing factors. First, the price fluctuation reflected common changes in cattle production costs, such as feed prices (corn and hay) and weather conditions (drought and winter storms). Figure 6 plots the weekly cattle price and four-month-lagged wholesale corn prices over time, showing that cattle price fluctuations often coincided with the rise and fall of corn prices. Second, the cartel operated in all four stockyards and coordinated pricing strategies to prevent sellers from arbitraging across markets.[23] Spot-market prices also varied dramatically from week to week. For sellers with a thin profit margin, even small price changes could significantly impact their income. For example, the average profit in 1909

[20]The distribution of the market sizes is very skewed. In 1916, nearly 2 million heads of cattle were slaughtered in Chicago, while in New York, the fifth largest market, only 0.4 million heads were slaughtered (Federal Trade Commission, 1919).

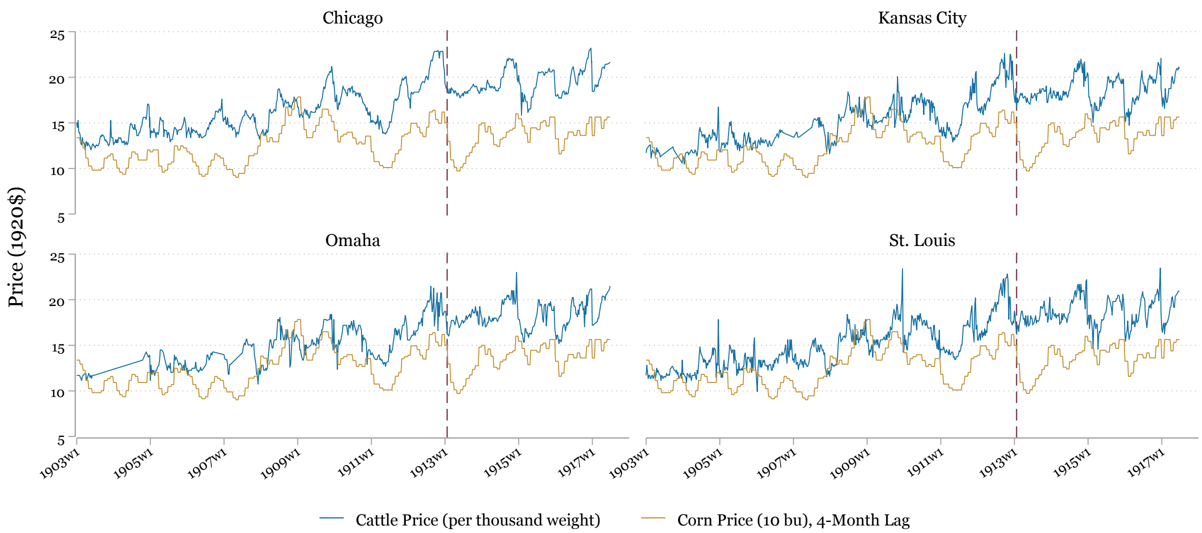
[21]Appendix B provides details on data sources for each market as well as variable construction and validation. The analysis also excludes observations with the top and bottom 1 percent of the cartel market share. Such extreme cases, including when the cartel purchased all or none of the cattle supply, coincided with temporary meatpacking plant closures or outbound railroad accidents.

[22]See Appendix Figure 1 for the total number of cattle that arrived at stockyards.

[23]A seller might not be satisfied with the price at the first market and could in theory try to ship the cattle to another stockyard, or split up their shipment to two stockyards to minimize price shocks. However, stockyard offices share the offering prices with the headquarter and other locations to ensure that sellers receive the same price at different locations. As a result, these practices were infrequent. See Federal Trade Commission (1919), volume 2, section 8 for examples of the telegrams.

was \$29.37 per head, as estimated by the Purdue Agricultural Experiment Station (Skinner, 1909). Thus, for a 1,000-lb steer, a \$0.3 drop in the wholesale price would reduce the profit by 10 percent.[24]

Figure 6: Cattle Price by Stockyards



Notes: Corn price is the monthly average No. 2 corn wholesale prices in Chicago.

5.2 Auxiliary Data

Cattle Production Cost and Weather. The main factors affecting cattle production are feed cost and weather conditions. To measure the fluctuations of these costs, I collect monthly wholesale prices of corn and hay in Chicago.[25] I also construct monthly averages of temperature and precipitation for the feedlot cattle production region, using county-level historical weather data from Bleakley and Hong (2017).[26] The analysis uses lagged monthly feed prices and weather data to approximate cost shocks. Additionally, because weather conditions can affect cattle sellers's decisions at the stockyard, I also collect weekly temperature and precipitation data from the National Oceanic and Atmospheric Administration, selecting stations closest to each of the four stockyards.[27]

Demand Instrument. Estimating the stockyard supply requires instrumenting for cartel prices. A natural choice for instruments is the prices of beef substitutes. To achieve this, I digitize the Bureau of Labor Statistics' *Wholesale Prices Series*, which includes weekly wholesale prices in a few major urban markets. The analyses use prices for chicken, eggs, and lard in New York City. I discuss the IV selection in more detail in Section 7.

[24] Cattle prices are measured in dollars per 100 pounds. Values are adjusted to 1920 dollars.

[25] Corn prices are available through the NBER Macro history database, series 04005, "U.S. Wholesale Price of Corn, Chicago." I digitize the monthly No. 1 baled Timothy hay prices from the Department of Agriculture's Yearbook.

[26] The averages are weighted by county areas. The sample includes the following key states in feedlot cattle production: Colorado, Iowa, Kansas, Minnesota, Missouri, North Dakota, New Mexico, Nebraska, Oklahoma, and South Dakota.

[27] The data were accessed through the NOAA past weather website.

6 Descriptive Evidence

I first present descriptive evidence on the impact of cartel manipulation on the stockyard market. Because government litigation forced the cartel to stop manipulating prices, I can test the predictions generated by the stylized model in Section 4 by comparing the aggregate market outcomes with and without cartel manipulation. Specifically, I estimate the following regression:

$$y_{kt} = \alpha \mathbb{1}(\text{Manipulation}) + \beta_x X_t + \beta_k K_{kt} + \eta_{kw} + \tau_{ky} + \epsilon_{kt}, \tag{9}$$

where y_{kt} is an aggregate market outcome variable for stockyard k at time t. $\mathbb{1}(\text{Manipulation})$ is an indicator variable equal to 1 during the manipulation period (before 1913), and α represents the average differences in the market outcomes. The results control for shocks common to all markets, X_t, which includes four-month-lagged wholesale prices of corn and hay as proxies for feed costs. It also includes four-month-lagged weather conditions, measured by the monthly average temperature and precipitation. K_{kt} represents local weather shocks that may affect sellers' decisions at the stockyard, which includes minimum and maximum temperature and precipitation for stockyard k at time t. η_{kw} is a stockyard-by-week-of-year fixed effect, which captures the seasonality of the cattle market at each stockyard. τ_{ky} is the stockyard-specific time trend. Standard errors are clustered by time, as the cartel coordinated prices across all markets.

Table 2 reports the estimated results for α. Under cartel manipulation, 21.9 percent more cattle were shipped to the stockyards, and cartel prices were 4.4 percent lower. These results are consistent with the model predictions from Section 4: the cartel manipulated the sellers to increase their posterior beliefs on higher states, leading them to expect higher prices. Because sellers made their shipment decisions based on their expected cartel prices, the higher expected prices led to an increase in shipments to the stockyards. With the additional shipment, the cartel purchased 40.4 percent more cattle at lower average prices. Estimates for other control variables are reported in Appendix Table 2.

I also compare sellers' margins over time. Sellers' margin is defined as the difference between stockyard cattle prices and input costs, which are approximated by four-month-lagged wholesale corn prices. Column (4) shows that under cartel manipulation, their margin was 24.1 percent lower. In other words, while the market structure remained unchanged, price manipulation allowed the cartel to further reduce the prices paid to small sellers.

I restrict the data to the period before April 1917, when the United States entered World War I, to avoid the confounding effects of the war on production. Prior to 1917, robust export demand from Europe drove up grain prices (Henderson et al., 2011). Rising corn prices affected cattle supply through the cost channel, which is controlled for in the analysis.

I conduct two robustness checks. First, I exclude Chicago to test whether the cartel successfully applied the manipulation strategy to all markets. Chicago dominated all other markets in terms of scale. It also received more media attention, which might amplify the effects of price fluctuations. The results in Appendix Table 3 show that the manipulation strategy indeed affected all markets.

Table 2: Market Outcomes with and without Cartel Manipulation

	(1) Total Shipment	(2) Price	(3) Cartel Quantity	(4) Sellers' Margin
$\mathbb{1}$(Manipulation)	1.164***	-0.831***	1.239***	-1.231***
	(0.126)	(0.197)	(0.094)	(0.188)
Cost Controls	Yes	Yes	Yes	No
Mean	5.31	18.74	3.06	5.11
% wrt Mean	21.92	4.43	40.45	24.10
Observations	2525	2439	2525	2439
Adjusted R-Squared	0.87	0.81	0.81	0.51

Note: "Sellers' Margin" is defined as the difference between cattle price and input cost, which is approximated by the sum of four-month lagged prices of corn and hay. Therefore, the estimations for sellers' margin (column 4) does not include the cost controls in the regression. "% wrt Mean" shows the estimated coefficient of the manipulation period dummy (first row) as a percentage of the variable's sample mean during the non-manipulation period. The number of observations differ due to missing data in cattle prices. Standard errors are clustered by (weekly) time to account for correlation across markets. * $p < 0.10$ **, $p < 0.05$, *** $p < 0.01$

The estimated parameters from the sample excluding Chicago are comparable in scale to the full sample results and are statistically significant. Second, since the cartel faced a prolonged public trial before suspending their collusive meetings, market outcomes during this period of legal uncertainty may not accurately reflect the cartel's typical strategies. Therefore, I exclude observations between December 1911, when the trial began, and January 1913, when the cartel finalized the joint holding company's dissolution. Appendix Table 4 shows that excluding the trial period does not change results.

7 Model and Estimation

In this section, I characterize and estimate the stockyard cattle supply. The analysis uses post-1913 data, when the cartel followed the standard monopsony strategy, to estimate the model primitives. The main goal is to quantify the effect of cartel manipulation by comparing observed market outcomes under manipulation with the counterfactuals suggested by the standard monopsony model.

Following Berry (1994), sellers' discrete choice between the cartel and the competitive market, as described in equation (4), implies that

$$\ln(s_{ckt}) - \ln(s_{okt}) = \gamma_c c_{kt} + \gamma_x X_t + \gamma_k K_{kt} + \eta_{kw} + \xi_{kt}, \tag{10}$$

where s_{ckt} is the share of cattle at market k purchased by the cartel at time t, and s_{okt} is the share of cattle that left stockyard k alive to be sold to the competitive market. c_{kt} is the cartel price at market k at time t. X_t, K_{kt}, and η_{kw} are cost factors, stockyard weather conditions, and stockyard week-of-the-year fixed effects, as in equation (9).[28] ξ_{kt} is the unobserved quality of cattle in the market. For refrigerated beef, packers primarily use prime-grade steers. However, qualities such as weight, whether the steers were dehorned, and so on may vary within the same grade of cattle

[28] X_t can also be viewed as a proxy for competitive market prices, which vary over time and were only determined by cost fluctuations.

and can thus be correlated with prices. The variability leads to the typical endogeneity problem in discrete choice models.

To identify γ_c, I need an instrument for cartel prices that is uncorrelated with cattle supply but influences the cartel's demand at the stockyard market. I use the prices of other perishable food items as this instrument. Specifically, I collect weekly price data for chicken, eggs, and lard from the *Wholesale Prices Series*. The choice of price instrument is primarily driven by data availability, as only a few perishable items have long weekly price series and were not produced by the meatpackers.[29]

Table 3 presents the results of estimating the price coefficient γ_c, as specified in equation (10). Column (1) reports the price coefficient for the logit model using ordinary least squares (OLS). As expected, without addressing price endogeneity, the price coefficient for the cattle supply cannot be properly recovered. Columns (2)–(5) report the first-stage results, where the dependant variable is the cartel's cattle prices. The results indicate that cattle prices are strongly correlated with the prices of other perishable animal products. Columns (6)–(10) report the price coefficient γ_c with the three different instruments. After accounting for price endogeneity, the estimations recover the positive price coefficient for the stockyard cattle supply. The IV results show similar estimates for the price coefficient despite using three different instruments.[30]

To interpret the coefficient, I calculate the stockyard cattle supply elasticity, markdown, and input share of revenue measures, all measured at the average price level. The bottom three rows in Table 3 present the estimates. When using chicken prices as an instrument, the estimates suggest that the spot-market supply is elastic, with the average price elasticity around 1.5. This corresponds to a markdown value of 1.7, meaning sellers received 60.3 percent of what they would have in a competitive market. The results are similar with other instruments.

Based on the production process described in Section 2, I make two assumptions to connect cattle supply to the cartel's output. First, the cartel faced a Leontief production function, as one cannot substitute cattle with other variable inputs. Consequently, the quantity of output (beef) is directly proportional to the quantity of input (cattle). Second, because cattle accounted for more than 90 percent of the variable cost of production, I only consider the cost of cattle and ignore the other input costs such as fuel and labor. Given the two assumptions, the cartel's marginal cost can be written as $mc_t = c_t + \frac{1}{\gamma_c}\frac{1}{1-s_{ct}}$. In the product market, the cartel was also a monopoly seller of beef. The equilibrium monopoly pricing implies

$$\eta = \frac{p_t - mc_t}{p_t} = \frac{1}{-e_D},$$

[29] The meatpackers dominated cured meat production and were also monopsony buyers in the livestock markets in urban centers like New York City, where they slaughtered and processed fresh beef and pork. Therefore, while other animal products may be closer substitutes for refrigerated beef, their prices may also respond to the supply conditions on the wholesale cattle market.

[30] Appendix Table 5 reports the estimates for other variables. Note that while the IV approach provides an unbiased estimation for the stockyard supply under monopsony, this cannot be applied to the manipulation period. When manipulating prices, the cartel did not set the stockyard prices in response to actual demand fluctuations but rather "pretended" to be in a different state.

Table 3: Spot-Market Supply

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS		First Stages			IV	
Dependent Variable	$\ln(s_{ckt}) - \ln(s_{okt})$		Cattle Price			$\ln(s_{ckt}) - \ln(s_{okt})$	
Cattle Price	0.024				0.185*	0.224***	0.339*
	(0.018)				(0.101)	(0.081)	(0.175)
Chicken Price		0.098***					
		(0.025)					
Egg Price			-2.793***				
			(0.605)				
Lard Price				6.272***			
				(2.162)			
Observations	773	673	688	686	673	688	686
Instrument					Chicken	Egg	Lard
Kleibergen–Paap F-statistic					15.29	21.33	8.41
Elasticity					1.52	1.84	2.78
Markdown					1.66	1.54	1.36
Input Share of Revenue (%)					60.28	64.79	73.58

Note: The table shows the regression coefficient γ_c described in equation (10). Estimations include weather and cost controls as well as stockyard-by-week-of-year fixed effects. The number of observations differ between the OLS and IV results due to missing data in the instrument. Standard errors are clustered by time. The elasticity of cattle supply with respect to the cartel price is $e_s = \gamma_c c_{kt}(1 - s_{ckt})$. Correspondingly, the cattle price markdown is $\psi_s = e_s^{-1} + 1$. Input share of revenue is the inverse of markdown, or $\frac{1}{\psi_s}$. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

where η is the monopoly markup and e_D is the demand elasticity for beef.

I collect weekly wholesale prices, p_t, in New York City from *The National Provisioner* to estimate the markup.[31] Table 4 presents the estimated markup and elasticity for both the manipulation and monopsony (non-manipulation) period. The estimated values are similar across the two periods. As the dominant supplier of beef in urban markets, the cartel enjoyed a 30 percent markup. This is consistent with the narrative evidence that the cartel continued to operate as a monopoly in the wholesale beef market, even though it adopted different strategies in the cattle input markets.

Table 4: Markup and Elasticity

	Markup			Elasticity		
	Mean	CI 5	CI 95	Mean	CI 5	CI 95
Manipulation (before 1913)	0.325	0.323	0.339	-3.020	-3.191	-3.023
Monopsony (after 1913)	0.317	0.315	0.330	-2.398	-3.239	-3.082

Note: Confidence intervals are calculated with 100 bootstraps.

8 Welfare Effects of Cartel Manipulation

I use the estimated parameters to construct counterfactual outcomes in both the input (cattle) and output (beef) markets for the manipulation period. I then examine two hypothetical scenarios:

[31] I use "Western dressed" prices, which refers to cattle carcasses processed by packers in the west and shipped to urban markets.

standard monopsony and symmetric oligopsony. The standard monopsony benchmark measures the potential welfare gains that antitrust agencies can attain by disrupting the manipulation strategy. The oligopsony case assumes that the litigation had successfully broken up the cartel and the five packers compete with each other in both the wholesale cattle and beef markets.

The top two rows in Table 5 present changes in the cattle markets. If the cartel switched to the monopsony strategy, it would purchase fewer cattle at higher prices. The average wholesale cattle price would increase by 30.4 percent, or be $4.74 higher. For small sellers, disrupting the manipulation would increase their profit margin by 60 percent.[32] Meanwhile, the average daily quantity purchased by the cartel would decrease by 19.7 percent, from 3,200 to 2,600 heads per day. In aggregate, this implies that, on average, the packers would process 15,000 fewer heads of cattle per week across the four stockyard markets. These changes in prices and cartel quantity align with the findings in Section 6, which show that price manipulation allowed the cartel to acquire more cattle at lower prices than in the standard monopsony case.

While disrupting cartel manipulation can recover some welfare loss, the improvement is relatively small compared to the case when the cartel is dissolved. If packers must compete in the input market (right panel in Table 5), they would process 28.1 percent, or 21,500 more heads of cattle per week. The average wholesale cattle price would also be $14.37 higher, almost double the average price under manipulation. The large difference also explains why cartel members quickly agreed to suspend their weekly collusive meetings, as described in Section 2: the gains from market manipulation are small compared to the litigation risk that may break up the cartel.

Table 5: Changes in Market Outcomes

	Monopsony			Oligopoly		
	Mean	CI 5	CI 95	Mean	CI 5	CI 95
Δ Stockyard Cattle Price ($1920)	4.74	-0.84	9.30	14.37	7.88	19.38
Δ Cartel Quantity (000s)	-0.63	-2.00	0.23	0.89	0.18	1.93
Δ Beef Wholesale Price ($1920)	1.15	-0.74	2.99	-2.19	-4.83	-0.52

The welfare effects on urban consumers are much smaller. The bottom row in Table 5 shows that switching to a standard monopsony would increase beef prices by 4.9 percent, or $1.15 per 100 pounds. The change in consumer welfare is relatively small compared to the additional cattle sales value: in 1917, an average urban household consumed 168 pounds of beef per year (Bureau of Labor Statistics, 1992). To maintain the same level of consumption, the average household would spend $1.93 more per year on beef. Compared to the manipulation case, breaking up the cartel would reduce the wholesale price by 9.4 percent, saving the average household $3.67 per year.

[32] This would increase sales value for a 1,000-lb cattle by $47.4. For comparison, the average profit for a head of cattle in 1909 was $29.37. See Skinner (1909) for the profit estimates. All dollar values are adjusted to 1920 dollars.

9 Conclusion

In this paper, I estimate the impact of signal manipulation by a monopsony cartel on the cattle market, focusing on the U.S. meatpacking cartel's case. Analyzing changes in government litigation that forced the cartel to switch from the signal manipulation strategy to a standard monopsony one, I find that the manipulation strategy led to a larger welfare loss for price-taking cattle sellers than what a standard monopsony model would suggest. By manipulating price signals, the cartel purchased more cattle at lower prices than it would have under a standard monopsony strategy. Without adopting new legislation or breaking up the cartel through forced divestiture, changes in antitrust enforcement forced the cartel to abandon the manipulation, which could increase the profit margin for small cattle sellers at a relatively low cost to urban consumers.

The historical case has important implications for contemporary markets. Without contracts or futures markets, which is often the case in developing countries, small sellers usually rely on spot markets for sales. However, recent work by Garrido, Kim, Miller, and Weinberg (2022) shows that sellers are not necessarily better off when they switch to contracts. Because contract prices are usually linked to the spot-market price, such arrangements distort packers' bidding strategies and end up depressing the price paid for cattle sold through either contracts or spot markets. Insufficient oversight of large buyers can lead to substantial distortions in the input market. Moreover, this paper highlights the difficulties involved in regulating monopsony power. Although cartel manipulation benefited consumers, these gains were outweighed by the more sizable losses to cattle farmers. Policies that primarily prioritize consumer welfare may hinder regulators' capacity to address the adverse effects of monopsony power on small producers.

References

Aduddell, Robert M., and Louis P. Cain. 1981. "Public Policy toward" The Greatest Trust in the World"." *Business History Review* 217–242. (P4)

American National Live Stock Association. 1909. *Proceedings of the Twelfth Annual Convention of the American National Live Stock Association.* (P6)

Anderson, Oscar Edward. 1953. *Refrigeration in America; a History of a New Technology and Its Impact.*. Princeton University Press. (P5)

Andrews, Frank. 1908. "Cost and Methods of Transporting Meat Animals." In *Yearbook of the United States Department of Agriculture*, US Government Printing Office. (P6)

Ashenfelter, Orley C., Henry Farber, and Michael R. Ransom. 2010. "Labor market monopsony." *Journal of Labor Economics* 28 (2): 203–210. (P2)

Asker, John, and Scott Hemphill. 2020. "A Study of Exclusionary Coalitions: The Canadian Sugar Combination, 1887-1889." *Antitrust Law Journal* 83 99. (P4)

Berger, David, Kyle Herkenhoff, and Simon Mongey. 2022. "Labor Market Power." *American Economic Review* 112 (4): 1147–93. (P2)

Berry, Steven T. 1994. "Estimating discrete-choice models of product differentiation." *RAND Journal of Economics* 242–262. (P3, 20)

Blair, Roger D., and Jeffrey L. Harrison. 2010. *Monopsony in Law and Economics.* Cambridge University Press. (P4)

Bleakley, Hoyt, and Sok Chul Hong. 2017. "Adapting to the weather: Lessons from US history." *Journal of Economic History* 77 (3): 756–795. (P18)

Bureau of Animal Industry. 1884. *Annual Report of the Bureau of Animal Industry.* US Government Printing Office. (P5)

Bureau of Corporations. 1905. *Report of the Commissioner of Corporations on the Beef Industry.* 58th Congress, 3d session. House. Document, Government Printing Office. (P5, 28)

Bureau of Labor Statistics. 1992. *Cost of Living in the United States, 1917-1919.* Inter-university Consortium for Political and Social Research, , https://doi.org/10.3886/ICPSR08299.v5. (P23)

Byrne, David P, and Nicolas De Roos. 2019. "Learning to coordinate: A study in retail gasoline." *American Economic Review* 109 (2): 591–619. (P4)

Byrne, David P, Nicolas de Roos, Matthew S Lewis, Leslie M Marx, and Xiaosong Andy Wu. 2023. "Asymmetric Information Sharing in Oligopoly: A Natural Experiment in Retail Gasoline."Technical report. (P4)

Chandler, Alfred D. 1993. *The Visible Hand.* Harvard University Press. (P4)

Chatterjee, Shoumitro. 2023. "Market Power and Spatial Competition in Rural India." *The Quarterly Journal of Economics* 138 (3): 1649–1711. (P2, 4)

Clemen, Rudolf Alexander. 1923. *The American Livestock and Meat Industry.* Johnson Reprint Corporation. (P5)

Commons, John R. 1904. "Labor conditions in meat packing and the recent strike." *Quarterly Journal of Economics* 19 (1): 1–32. (P7)

Delabastita, Vincent, and Michael Rubens. 2023. "Colluding Against Workers." working paper. (P4)

Donna, Javier D, and José-Antonio Espín-Sánchez. 2023. "The Illiquidity of Water Markets." *Review of Economics Studies.* (P4)

Dube, Arindrajit, Jeff Jacobs, Suresh Naidu, and Siddharth Suri. 2020. "Monopsony in online labor markets." *American Economic Review: Insights* 2 (1): 33–46. (P2)

Federal Trade Commission. 1919. *Food Investigation: Report of the Federal Trade Commission on the Meat packing Industry.* Goverment Printing Office. (P5, 7, 9, 10, 17, and 30)

Garrido, Francisco, Minji Kim, Nathan Miller, and Matthew Weinberg. 2022. "Buyer Power in the Beef Packing Industry: An Update on Research in Progress." (P4, 24)

Genesove, David, and Wallace P. Mullin. 2001. "Rules, communication, and collusion: Narrative evidence from the Sugar Institute case." *American Economic Review* 91 (3): 379–398. (P4, 9)

Haines, Michael, Price Fishback, and Paul Rhode. 2018. *United States Agricultural Data, 1840-2012*. Inter-university Consortium for Political and Social Research, , `https://doi.org/10.3886/ICPSR35206.v4`. (P6)

Hall, Kermit L., James W. Ely, and Joel B. Grossman. 2005. *The Oxford Companion to the Supreme Court of the United States*. Oxford University Press. (P8)

Harrington, Joseph E., and Andrzej Skrzypacz. 2011. "Private monitoring and communication in cartels: Explaining recent collusive practices." *American Economic Review* 101 (6): 2425–49. (P4)

Hemphill, C. Scott, and Nancy L. Rose. 2018. "Mergers That Harm Sellers." *Yale Law Journal* 127 (7): 2078. (P2, 4)

Henderson, Jason, Brent Gloy, and Michael Boehlje. 2011. "Agriculture's boom-bust cycles: is this time different?" *Economic Review-Federal Reserve Bank of Kansas City* 83. (P19)

Inderst, Roman, and Nicola Mazzarotto. 2008. "Buyer power in distribution." In *ABA Antitrust Section Handbook, Issues in Competition Law and Policy*, Volume 3. 1953–1978, ABA. (P2)

Krueger, Alan B, and Orley Ashenfelter. 2022. "Theory and evidence on employer collusion in the franchise sector." *Journal of Human Resources* 57 (S): S324–S348. (P2)

Lamoreaux, Naomi R. 1988. *The great merger movement in American business, 1895-1904*. Cambridge University Press. (P4)

Lamoreaux, Naomi R. 2019. "The Problem of Bigness: From Standard Oil to Google." *Journal of Economic Perspectives* 33 (3): 94–117. (P4, 8)

Lamoreaux, Naomi R. 2023. "Antimonopoly and State Regulation of Corporations in the Gilded Age and Progressive Era." *Antimonopoly and American Democracy*. (P4)

Levenstein, Margaret C., and Valerie Y. Suslow. 2006. "What Determines Cartel Success?" *Journal of Economic Literature* 44 (1): 43–95. (P4)

Libecap, Gary D. 1992. "The rise of the Chicago packers and the origins of meat inspection and antitrust." *Economic Inquiry* 30 (2): 242–262. (P4)

Mailath, George J. 1989. "Simultaneous signaling in an oligopoly model." *The Quarterly Journal of Economics* 104 (2): 417–427. (P11)

Manning, Alan. 2003. *Monopsony in Motion: Imperfect Competition in Labor Markets*. Princeton University Press. (P2)

Marshall, Robert C., and Leslie M. Marx. 2012. *The Economics of Collusion: Cartels and Bidding Rings*. MIT Press. (P4)

Mester, Loretta J. 1992. "Perpetual signalling with imperfectly correlated costs." *The Rand Journal of Economics* 548–563. (P11)

Röller, Lars-Hendrik, and Frode Steen. 2006. "On the workings of a cartel: Evidence from the Norwegian cement industry." *American Economic Review* 96 (1): 321–338. (P4)

Rubens, Michael. 2023. "Market structure, oligopsony power, and productivity." *American Economic Review* 113 (9): 2382–2410. (P2, 4)

Skaggs, Jimmy M. 1986. *Prime Cut: Livestock Raising and Meatpacking in the United States, 1607-1983*. Texas A and M University Press. (P5)

Skinner, John Harrison. 1909. *Bulletins of the Agricultural Experiment Station, Winter Steer Feeding, 1908-09*. (136): , Purdue University Agricultural Experiment Station. (P6, 18, and 23)

United States Congress. 1912. *Congressional Record: Proceedings and Debates of the Sixty-Second Congress, Second Session*. (Volume XLVIII, Part VII): , U.S. Government Printing Office. (P27)

Werden, Gregory J. 2007. "Monopsony and the Sherman Act: Consumer Welfare in a New Light." *Antitrust Law Journal* 74 (3): 707. (P2, 4)

Yeager, Mary. 1981. *Competition and Regulation: The Development of Oligopoly in the Meat Packing Industry*. Volume 2. JAI Press (NY). (P2, 8)

Appendices

A History of the Meatpacking Litigation

The table below summarizes the main events regarding the litigation process against the meatpackers. Dates and events are summarized from the materials presented at the House of Representatives debate on May 25,1912 (United States Congress, 1912) and various newspaper articles.

Meatpacking Litigation Time Line

Date		Event
1902	May	Government filed petition for an injunction against the Beef Trust Judge Grosscup issued temporary injunction
	August	Packers filed a demurrer against the injunction
1903	April	Judge Grosscup overruled packers' demurrer petition and the injunction remained in force[a]
	May	Packers appeal to the Supreme Court against the injunction
1904	April	The Bureau of Corporations started an investigation in the meatpacking industry
1905	January	Supreme Court affirmed Judge Grosscup's injunction from 1903 [b]
	February	The government sought criminal indictment against the packers for antitrust violations
	July	Federal grand jury in Chicago indicted the Big Five and their top executives for violation of the Sherman Act
	October	Packers plead for immunity claiming that packers provided testimony for the Bureau of Corporation under compulsion
1906	March	Judge held that individuals were immune from the criminal prosecution, but indictment for the corporation stands
	October	Department of Justice decided to drop the case
1910	January	Department of Justice brought new charges against the packers
	March	Grand jury indicted the Big Five and their executives for violating the Sherman Act.
1911	December	Trial began
1912	March	Trial lasted three months. Jury found the packers not guilty of violating the criminal section of the Sherman Act.
	May	Attorney General announced that the government was prepared to file a civil suit against the packers
	June	Packers announced their intention to dissolve the joint holding company, National Packing Co.
	July	Packers submitted to the Department of Justice the dissolution plan
1913	January	Dissolution finalized

[a] *Swift & Co. v. United States* (122 F. 529)
[b] *Swift & Co. v. United States*, 196 U.S. 375

B Data Collection and Variable Construction

Cattle Market I collected the cattle shipment and price data from annual reports and trade journals. The table below listed the data sources for each market.

Stockyard Market Data Sources

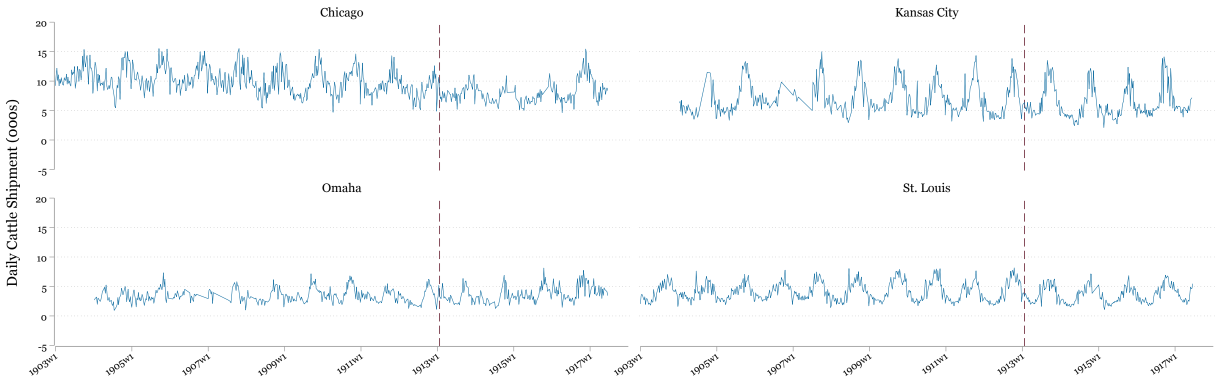
Market	Shipment	Price
Chicago	Union Stockyard Annual Report	*The National Provisioner*,*Drover's Journal*, Chicago Board of Trade Annual Report
Kansas City	*The National Provisioner*	*The National Provisioner*
Omaha	*The National Provisioner*, *Nebraska Bee*	*The National Provisioner*, *Nebraska Bee*
St. Louis	Merchants' Exchange of St Louis *Annual Statement of the Trade and Commerce*	*Annual Statement of the Trade and Commerce*

Though cattle prices are available by type and grade, I only use the average price for top-grade steers ("Prime" or "Choice") in the analysis for two reasons. First, the price for the top grade is the only category consistently reported over the whole time period. Second, refrigerated beef primarily came from the most heavy-weight ones and thus most relevant to the cartel manipulation. Bureau of Corporations (1905) reported that the average weight of cattle purchased a major packer in Chicago between 1902 and 1904 is 1,168 lbs, close to the average standard for "Choice" steer of 1,000 to 1,200 lbs. Heifers and bulls were either purchased by cattlemen for breeding or sold to local butchers since the smaller size does not justify being shipped afar as refrigerated beef.

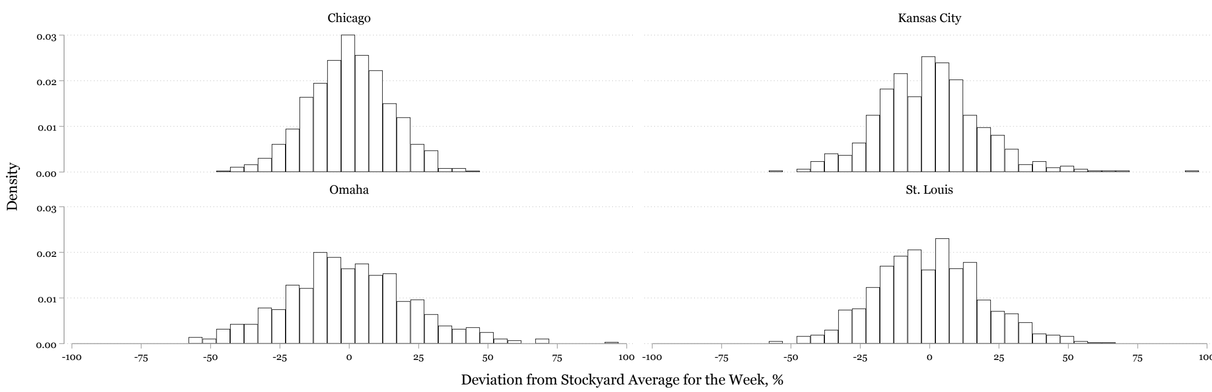
For all the analysis, sample exclude periods when the stockyards were closed due to quarantine or extreme weather or when less than two days of trading data were reported. When estimating the logit model, I also exclude the top and bottom 1% of observations to avoid distortion of extreme values.

Cattle supply exhibits significant variations from week to week. Appendix Figure 1(a) shows the average daily shipment for each stockyard. The cattle supply exhibits apparent seasonality, driven by the natural production cycle of cattle. The total number of cattle arriving at the stockyard can also change dramatically even within a short period, since a large number of cattle that can potentially be shipped to the market for each week. To illustrate this, for each stockyard, I calculate the percentage deviation of each week from the week-of-the-year averages (i.e. week 1 of each year). The value thus reflects how much the total number of cattle arrived at each market fluctuates after accounting for seasonal fluctuations. Appendix Figure 1(b) shows the distribution of the weekly deviations for each market. More than 50 percent of the observations deviated from the week-of-the-year average by 10%, and more than 80 percent deviated for more than 20%. Appendix Figure 1(c) displays the weekly variation for a three-year period as an example.

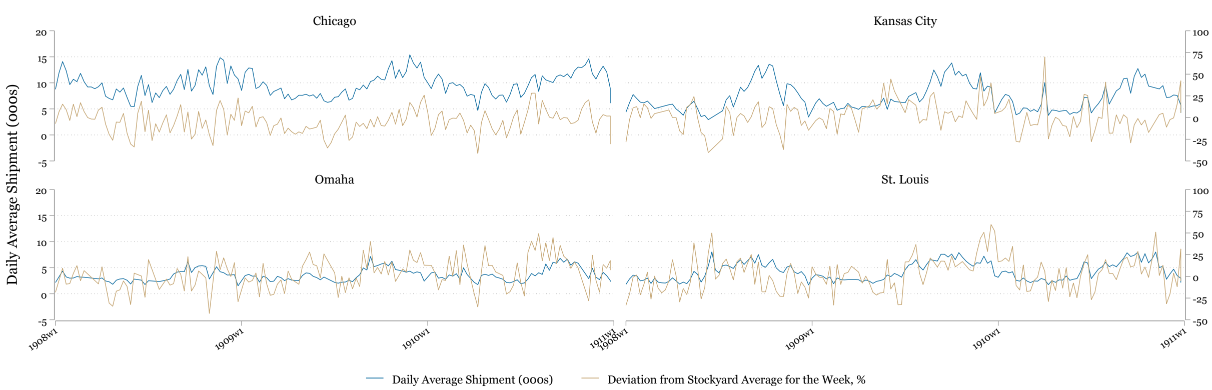
Appendix Figure 1: Shipment into Stockyard Markets



(a) Average Daily Shipment into the Stockyards,1903-1917



(b) Distribution of Deviation from Week-of-Year Average



(c) Example of Deviation from Week-of-Year Average,1908-1910

Notes: Deviation is the percentage difference between the shipment and the week-of-year averages. The week-of-year average shipment is calculated separately for each stockyard, with and without manipulation.

Appendix Table 1: Concentration of Refrigerated Beef Production, 1916

	(1) Head Slaughtered	(2) "Big Five", %	(3) Interstate Slaughter, %
Chicago	1,949,735	87.1	24.5
Kansas City	1,169,658	99.6	14.7
Omaha	806,863	100.0	10.2
St Louis	694,715	89.2	8.7
New York City	409,917	97.7	5.2
St Joseph	311,848	99.4	3.9
Fort Worth	364,014	100.0	4.6
St Paul	230,452	100.0	2.9
Sioux	203,482	100.0	2.6
Oklahoma City	174,541	100.0	2.2
Top 10 Stockyard	6,315,225	94.6	79.5

Note: Data from Federal Trade Commission (1919). Total number of cattle slaughtered for interstate trade in 1916 was 7.9 million.

Appendix Table 2: Market Outcomes With and Without Cartel Manipulation

	(1) Total Shipment	(2) Price	(3) Cartel Quantity	(4) Sellers' Margin
𝟙(Manipulation)	1.164***	-0.831***	1.239***	-1.231***
	(0.126)	(0.197)	(0.094)	(0.188)
Average Temperature, 4-Month Lag	0.003	-0.010	0.001	0.001
	(0.008)	(0.010)	(0.006)	(0.014)
Average Precipitation, 4-Month Lag	-0.110**	-0.205***	-0.012	-0.547***
	(0.051)	(0.068)	(0.035)	(0.096)
Min Temperature (F)	-0.011	-0.030**	-0.014**	-0.043**
	(0.010)	(0.012)	(0.007)	(0.018)
Max Temperateure (F)	0.008	0.023**	0.006	0.036**
	(0.008)	(0.010)	(0.006)	(0.015)
Precipitation (inch)	-0.332	0.355	-0.148	0.224
	(0.214)	(0.255)	(0.138)	(0.349)
Corn Price, 4-Month Lag (1920$)	-0.103***	0.445***	-0.071***	
	(0.019)	(0.027)	(0.014)	
Hay Price, 4-Month Lag (1920$)	-0.499***	0.580***	-0.362***	
	(0.066)	(0.081)	(0.045)	
Constant	-131.531***	-626.003***	-127.528***	-332.197***
	(34.465)	(50.615)	(25.614)	(37.566)
Cost Controls	Yes	Yes	Yes	No
Mean	5.31	18.74	3.06	5.11
% wrt Mean	21.92	4.43	40.45	24.10
Observations	2525	2439	2525	2439
Adjusted R-Squared	0.87	0.81	0.81	0.51

Note: "Sellers' Margin" is defined as the difference between cattle price and input cost, which is approximated by the sum of four-month lagged prices of corn and hay. Therefore, the estimations for sellers' margin (column 4) does not include the cost controls in the regression. "% wrt Mean" shows the estimated coefficient of the manipulation period dummy (first row) as a percentage of the variable's sample mean during the non-manipulation period. The numbers of observations differ due to missing data in cattle prices. Standard errors are clustered by (weekly) time to account for correlation across markets. * $p < 0.10$ **, $p < 0.05$, *** $p < 0.01$

Appendix Table 3: Market Outcomes Excluding Chicago

	(1) Total Shipment	(2) Price	(3) Cartel Quantity	(4) Sellers' Margin
Cartel Manipulation	1.229***	-1.124***	1.118***	-1.459***
	(0.136)	(0.200)	(0.095)	(0.197)
Cost Controls	Yes	Yes	Yes	No
Mean	4.46	18.52	2.93	4.86
% wrt Mean	27.55	6.07	38.22	30.02
Observations	1820	1735	1820	1735
Adjusted R-Squared	0.82	0.81	0.74	0.51

Note: "Sellers' Margin" is defined as the difference between cattle price and input cost, which is approximated by the four-month lagged prices of corn and hay. Thus, the estimations for sellers' margin (column 4) does not include the cost controls in the regression. "% wrt Mean" shows the estimated coefficient of the manipulation period dummy (first row) as a percentage of the variable's sample mean during the non-manipulation period. Standard errors are clustered by week-of-year . * $p < 0.10$ **, $p < 0.05$, *** $p < 0.01$

Appendix Table 4: Market Outcomes Excluding Trial Period

	(1) Total Shipment	(2) Price	(3) Cartel Quantity	(4) Sellers' Margin
Cartel Manipulation	1.333***	-1.465***	1.178***	-2.382***
	(0.142)	(0.196)	(0.101)	(0.252)
Cost Controls	Yes	Yes	Yes	No
Mean	4.46	18.52	2.93	4.86
% wrt Mean	29.88	7.91	40.26	49.02
Observations	1653	1577	1653	1577
Adjusted R-Squared	0.82	0.82	0.74	0.55

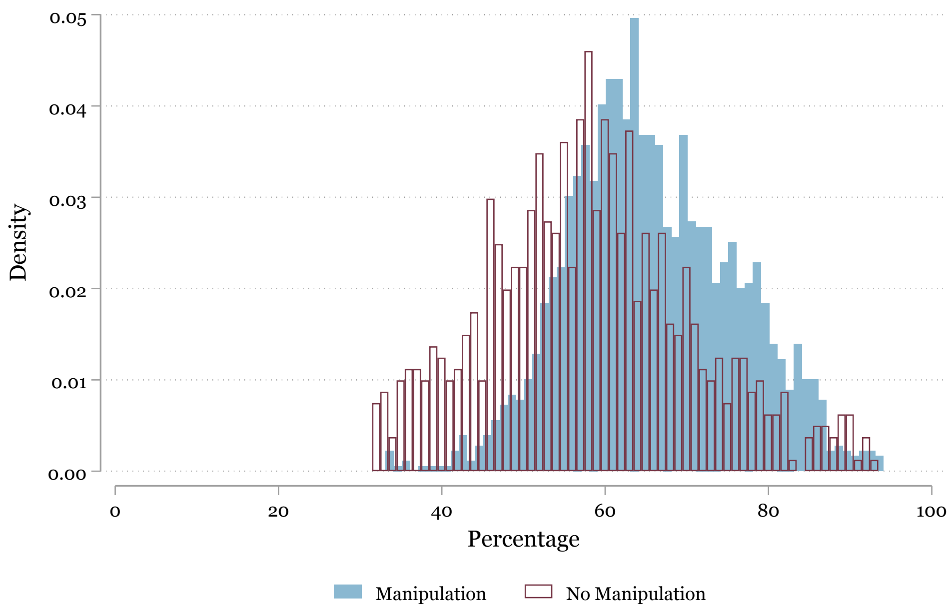
Note: Sample excluded observations between December 1911, when the trial began, and July 1912, when the cartel submitted their dissolution play to the justice department. Standard errors are clustered by week-of-year . * $p < 0.10$ **, $p < 0.05$, *** $p < 0.01$

Appendix Table 5: Detailed Estimates for Spot Market Supply Parameters

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS		First Stages			IV	
Dependent Variable	$\ln(s_{ckt}) - \ln(s_{okt})$		Cattle Price			$\ln(s_{ckt}) - \ln(s_{okt})$	
Cattle Price	0.024				0.185*	0.224***	0.339*
	(0.018)				(0.101)	(0.081)	(0.175)
Average Temperature, 4-Month Lag	-0.000	0.031	0.036**	0.027	-0.004	-0.006	-0.009
	(0.005)	(0.022)	(0.018)	(0.021)	(0.008)	(0.008)	(0.010)
Average Precipitation, 4-Month Lag	-0.049	-0.147	-0.317***	-0.086	-0.030	-0.023	-0.001
	(0.033)	(0.122)	(0.120)	(0.129)	(0.047)	(0.048)	(0.063)
Min Temperature (F)	-0.002	-0.063***	-0.055**	-0.050**	0.008	0.010	0.018
	(0.007)	(0.022)	(0.024)	(0.022)	(0.011)	(0.012)	(0.014)
Max Temperateure (F)	0.001	0.036*	0.034	0.030	-0.006	-0.008	-0.013
	(0.006)	(0.020)	(0.021)	(0.020)	(0.009)	(0.009)	(0.011)
Precipitation (inch)	0.289*	0.124	-0.006	0.188	0.310	0.278	0.268
	(0.154)	(0.405)	(0.410)	(0.436)	(0.188)	(0.197)	(0.227)
Corn Price, 4-Month Lag (1920$)	0.037**	0.365***	0.219***	0.354***	-0.011	-0.024	-0.063
	(0.015)	(0.058)	(0.070)	(0.061)	(0.039)	(0.033)	(0.063)
Hay Price, 4-Month Lag (1920$)	-0.166***	0.008	-0.004	0.040	-0.203*	-0.197*	-0.203
	(0.060)	(0.318)	(0.364)	(0.318)	(0.111)	(0.116)	(0.148)
Chicken Price		0.098***					
		(0.025)					
Egg Price			-2.793***				
			(0.605)				
Lard Price				6.272***			
				(2.162)			
Constant	0.040						
	(0.500)						
Observations	773	673	688	686	673	688	686
Instrument					Chicken	Egg	Lard
Kleibergen–Paap F-statistic					15.29	21.33	8.41

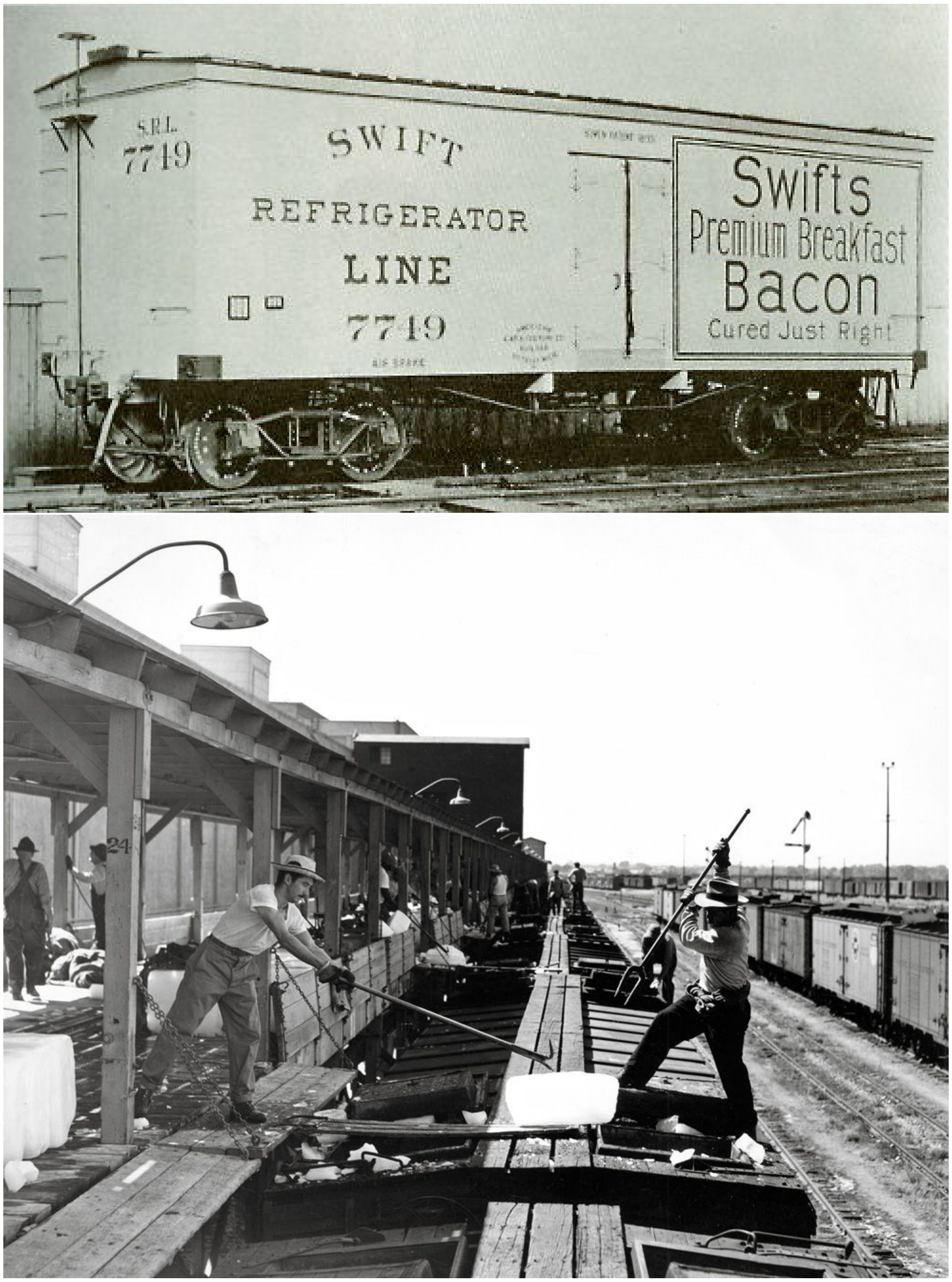
Note: The table shows the regression coefficient γ_c described in equation (10). Estimations include weather and cost controls, as well as week-of-year by market fixed effects. The numbers of observations differ between the OLS and IV results due to missing data in the instrument. Standard errors are clustered by time. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix Figure 2: Percentage of Cattle Purchased by Cartel Members at Stockyard Markets



Notes: See Appendix B for data sources.

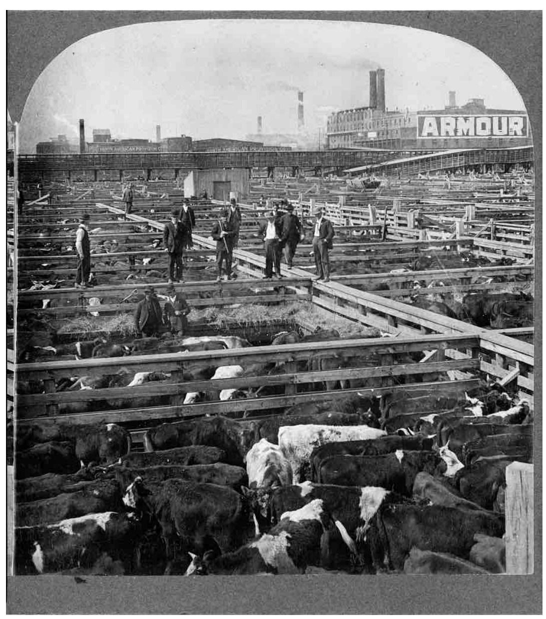
Appendix Figure 3: Swift Ice-Refrigerated Rail Car and Ice-Manufacturing Plant



Appendix Figure 4: Cattle Slaughter Relied Primarily on Manual Labor

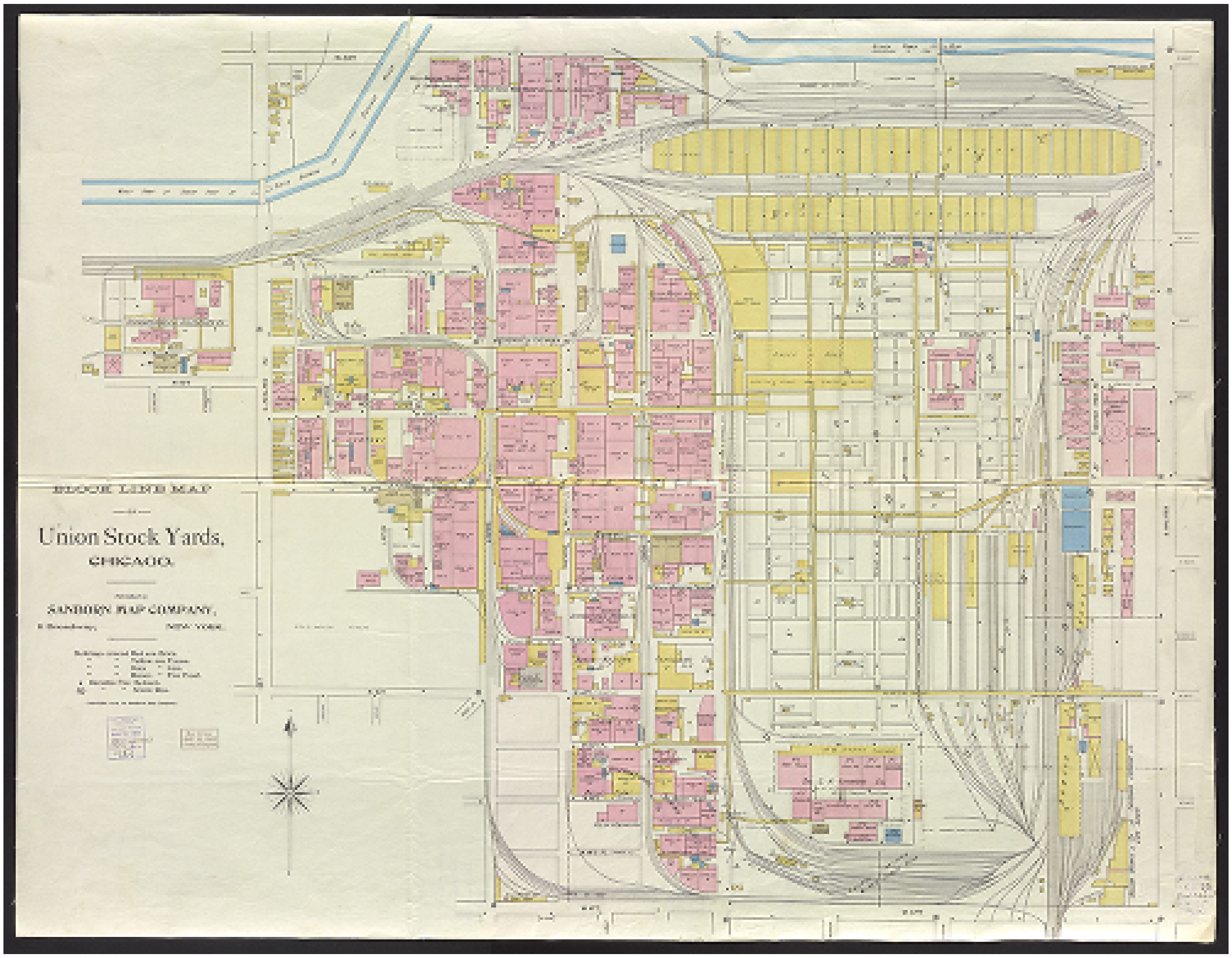
Note: H.C. White Co. Chicago - Meat Packing Industry: dressing beef–removing hides and splitting backbones, Swift's Packing House, Chicago, U.S.A. Chicago Illinois, 1906. North Bennington, Vt.: H.C. White Co., Publishers. Photograph. https://www.loc.gov/item/2006679958/.

Appendix Figure 5: Buyers at Chicago's Union Stock Yards, 1909



Note: *In the heart of the Great Union Stock Yards, Chicago, U.S.A.* Chicago Illinois, ca. 1909. Photograph. https://www.loc.gov/item/89711602/.

Appendix Figure 6: 1903 Map of Chicago's Union Stock Yards



Note: Digital map accessed through the University of Illinois at Urbana-Champaign Map Library. The pink areas were meatpacking plants and other by-product manufacturing facilities.