Monopsony, Cartels, and Market Manipulation: Evidence from the U.S. Meatpacking Industry

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July 20, 2023

Abstract

If a monopsony buyer manipulates market signals used by small sellers, it can create larger welfare loss than stated by standard models. This paper quantifies the effects of cartel signal manipulation on both the input and product markets by examining the U.S. meatpacking cartel from 1903 to 1917. The analyses leverage changes in antitrust enforcement that forced the cartel to stop manipulating market price signals and switch to a market share agreement. I quantify the welfare loss by comparing the observed market outcomes under the manipulation strategy with counterfactuals from the standard monopsony model without manipulation. Absent signal manipulation, wholesale cattle prices would increase by 23%, and 15,000 heads more cattle would be sold per week, while beef prices would be 6% lower, and a household would save $3.6 per year.

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

Key Words: monopsony, cartel, market manipulation, meatpacking

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1 Introduction

Policymakers and academics are increasingly concerned about the anti-competitive effects of monopsony (buyer) power in a wide range of industries.[1] However, despite recent policy efforts to address these adverse effects,[2] economic theory provides a limited understanding of monopsonistic cartel strategies. In particular, standard monopsony models focus primarily on immediate responses to cartel strategies. However, a monopsonistic buyer can potentially manipulate market signals at a cost. For markets with substantial time to ship or time to build, sellers must make future production or shipment decisions based on such signals. Without considering potential signal manipulation, the canonical model may understate the welfare loss from a monopsonistic cartel.

This paper estimates the impact of the cartel signal manipulation strategy on both the input and product markets by analyzing the U.S. meatpacking cartel. In the early 20th century, five meatpackers formed one of the largest manufacturing cartels in American history. The cartel dominated both the input market (cattle) and product market (beef): the five packers purchased 95% of cattle sold at the ten largest stockyards and produced more than 80% of refrigerated beef for urban markets. In 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 well suited to examining the effect of a cartel manipulation strategy. First, because the cartel was eventually challenged in court, the resulting litigation created detailed documentation on the cartel's manipulation strategies. The court found that the 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."[3] Second, exogenous changes in the regulatory environment forced the cartel to switch from the aforementioned manipulation strategy to a standard cartel market share agreement in 1913, while other market features remained unchanged. Thus, I observe the market outcomes under both the manipulation and standard monopsony strategies but with the same market participants. This allows me to compare the empirical outcomes under the cartel manipulation to counterfactuals suggested by the well-understood monopsony model.

[1] In *The United States v. Apple, 952 F. Supp. 2d 638*, the court found "Apple orchestrated a price-fixing conspiracy with five major e-book publishers." In *Knevelbaard Dairies v. Kraft Foods, Inc., 232 F.3d 979*, the court charged the manufacturer for unlawful manipulation of the cheese market. More recently, in 2022, the court blocked the proposed merger between Penguin Random House and Simon & Schuster (*The United States v. Bertelsmann SE & CO. KGaA, et al.*) on the grounds that the merger may increase monopsony power and harm authors. For empirical analyses of monopsony power, see Dube, Jacobs, Naidu, and Suri (2020), Ashenfelter, Farber, and Ransom (2010), and Manning (2003) on the labor market, Inderst and Mazzarotto (2008) on retail distribution, Morlacco (2019) on input trade, and Rubens (2021) and Chatterjee (2019) on agricultural products.

[2] The Department of Justice challenged a merger on the ground of increasing monopsony power (Cargill and Continental Grain Company, 1999, Anthem and Cigna, 2016) and brought enforcement against firms abusing monopsony power in labor market (*The United States v. Hee et al.*, 2022). In January 2022, the Federal Trade Commission and the Department of Justice announced that the agencies would broaden the scope of merger guidelines to address the potential impact of monopsony power ("Request for Information on Merger Enforcement").

[3] *United States v. Swift et al. (122 F 529).*

I first introduce the narrative evidence from court filings on the manipulation strategy. I then use a simple, stylized model of Bayesian persuasion to show that the manipulation can be sustained in a Perfect Bayesian Nash Equilibrium. In equilibrium, the sellers' optimal strategy is to follow the signal, despite knowing that the signals are not always truthful.

To conduct the empirical analysis, I compiled a novel data set consists of weekly market information from 1903 to 1917. The main variables of interest are cattle shipment to the stockyard wholesale markets, spot market prices, and the corresponding quantities purchased by the cartel. The weekly data were collected from a range of primary sources, including annual reports of stockyard companies and merchant exchanges, as well as livestock trade journals such as *The National Provisioner* and *The Drover's Journal*. The data covers the four largest stockyards, which collectively produced more than 58% of U.S. refrigerated beef. In addition, I also collected monthly wholesale corn and hay prices as a proxy for input costs, and wholesale prices of live hogs in New York City as an instrument variable for demand shocks.

The analysis consists of three main parts. I start by providing descriptive evidence on how cartel manipulation affected the cattle wholesale market. I first show that such manipulation led to different aggregate market outcomes: under manipulation, 22% more cattle were shipped to the stockyards for sale, yet the cattle wholesale price was 4.5% lower. I also show that the cartel successfully manipulated sellers' (cattlemen) shipment decisions: under cartel manipulation, higher shipment quantities did not correspond to higher realized prices. This is consistent with the narrative evidence and the model that sellers would follow the signal, even though the signals were manipulated and did not always reflect the realized states. Finally, I also show that no firm deviated from the cartel market share agreement after the packers suspended the weekly meeting. In other words, after 1913, the market outcomes are consistent with the standard monopsony model.

However, the reduced-form results provide limited information about the effects of cartel manipulation on the market. To measure the level of distortion created by the cartel manipulation, one needs the counterfactual market outcomes absent of manipulation, which requires a structural model to capture the cartel strategies and sellers' responses. Therefore, in the second part of the analysis, I construct and estimate a model of the cattle wholesale market. On the cattle supply side, I use a discrete choice model (Berry, 1994): cattlemen maximize the payoffs by choosing between the cartel and the outside competitive market. To address the price endogeneity issue, I use prices of a beef substitute in the urban market (i.e., live hogs) as an instrumental variable to trace out the spot market cattle supply curve. On the beef demand side, I use the Almost Ideal Demand System (AIDS) (Deaton and Muellbauer, 1980) with two-stage budgeting to estimate urban households' demand for beef. The cartel chooses the price at the cattle market to maximize profit given the cattle supply and beef demand. Both the cattle supply and beef demand are estimated separately using data *after* 1913 when the cartel was forced to abandon the manipulation strategy.

In the third part of the analysis, I use the estimated model primitives to solve for counterfactual market outcomes during the manipulation period, i.e., *before* 1913. Assuming that cattlemen and urban consumers behave in the same way as they did during the post-1913 period, the standard monopsony model recovers the counterfactual cattle wholesale prices and cartel quantities as well as downstream wholesale beef prices. The difference between the observed market outcomes under the manipulation strategy and the counterfactuals is, therefore the "additional" damage of the cartel manipulation not captured by standard models.

The main empirical strategy measures the effects of the cartel manipulation strategy by comparing the counterfactuals predicted by the standard monopsony model with the observed market outcomes under the manipulation strategy. This approach exploits the unique data structure by taking the market outcomes under the cartel manipulation as given. Instead of imposing any specific belief structures on the agents, I focus on estimating the well-understood monopsony model and quantifying the aggregate impact of the manipulation strategy by comparing the observed market outcomes with the theoretical counterfactuals. In spirit, the analysis is similar to recent works that study market distortions in complicated economic or institutional environment by comparing empirical outcomes with model benchmarks.[4]

I find two sets of key results. First, regarding the cattle wholesale market, cartel manipulation causes more damage to small sellers than what is suggested by the standard monopsony benchmark. Without the manipulation, the average cattle wholesale price would increase by 23.4%, which would increase the profit margin by 57% for the sellers. The average total quantity purchased by the cartel would also increase by 14%, or 15,000 more heads of cattle per week sold at the four stockyards. Second, regarding the downstream beef wholesale market, the manipulation strategy hurts urban consumers by reducing the beef supply and increasing household food expenditure. However, the effects are much smaller: without cartel manipulation, downstream wholesale beef prices would reduce by 6%, and total household food expenditure would reduce by $3.6 per year.

My research contributes to three strands of existing literature. First, it quantifies the effect of a monopsony cartel manipulation on the input market. A growing literature on buyer power and imperfect competition in the agricultural markets (Chatterjee, 2019; Bergquist and Dinerstein, 2020; Rubens, 2021; Garrido, Kim, Miller, and Weinberg, 2021) documents the negative effect of dominant buyers on prices. In addition, recent research from legal and antitrust policy perspectives calls for more attention to monopsony's adverse effects on both sellers and overall market efficiency (Blair and Harrison, 2010; Hemphill and Rose, 2018; Werden, 2007). To my best knowledge, this paper is the first to consider the monopsony strategy with market signal manipulation. The results show that the canonical model understates the welfare loss from monopsonistic market power. Moreover, the case of the meatpacking cartel shows that when a cartel dominates both the input and the product market, the manipulation can lead to welfare loss to both upstream sellers and downstream consumers.

[4]See Borenstein, Bushnell, and Wolak (2002) on the California electricity market, Asker, Collard-Wexler, and De Loecker (2019) on OPEC oil production, and Rafey (2019) on the Australian water market.

Second, this paper is related to the literature on the rise of industrial cartels and antitrust regulations during the Progressive Era. The meatpacking cartel was one of the largest manufacturing cartels in U.S. history and was among the first to be challenged in court. Prior research has detailed the cartel's development (Yeager, 1981; Chandler, 1993; Libecap, 1992) and how competition policies evolved in response to the new market structure (Aduddell and Cain, 1981; Lamoreaux, 2019; Sawyer, 2019). I contribute to the historical analyses by documenting and quantifying the effect of a specific cartel manipulation strategy on the market. In addition, while previous research focuses on regulatory evolution, this paper leverages changes in the legal environment that were not created by new regulations. The results suggest that development in legal interpretation and antitrust enforcement can rein in certain anti-competitive behaviors and improve welfare under the existing legal framework.

Finally, this paper contributes to the literature on the inner workings of cartels. Past research dissects specific cartel strategies across different markets and regulatory environments (Marshall and Marx, 2012; Röller and Steen, 2006; Genesove and Mullin, 2001; Harrington and Skrzypacz, 2011). I present new evidence that a monopsonistic cartel can employ a more complicated strategy to manipulate market signals. This paper provides a first-order estimate on the cartel damage and expands our understanding of the strategic toolkit available for cartels.

2 Historical Background of the Meatpacking Cartel

In this section, I offer some historical background on the meatpacking industry and the meatpacking cartel, and I describe the regulatory environment's evolution in the early twentieth century. The nature of the livestock market and the meatpacking industry provides the basis for the structural model I describe in section 4. In addition, the changes in the regulatory environment described here allow me to identify key parameters for the model I describe in section 8.

2.1 History of the Meatpacking Industry

The introduction of mechanical refrigeration and the subsequent adoption of ice-refrigerated rail cars by Chicago meatpackers in the 1880s created the modern meatpacking industry (Anderson, 1953). Instead of shipping live cattle to eastern markets, packers could ship just the carcasses in tightly packed refrigerated rail cars. On the one hand, refrigerated rail cars significantly reduced the shipping cost of beef: carcasses could be shipped for one-third the cost of shipping live cattle (Bureau of Animal Industry, 1884; Skaggs, 1986). On the other hand, the fixed cost of constructing specialized rail cars, ice plants, and refrigerated warehouses along the transportation lines created high barriers to entry.[5] By the early 20th century, five firms (the "Big Five") had come to dominate the meatpacking industry.

In the cattle market, the Big Five were the dominant buyers. In 1916, they slaughtered 6.5 million head of cattle, or 82.2% of all wholesale refrigerated beef sold in interstate commerce

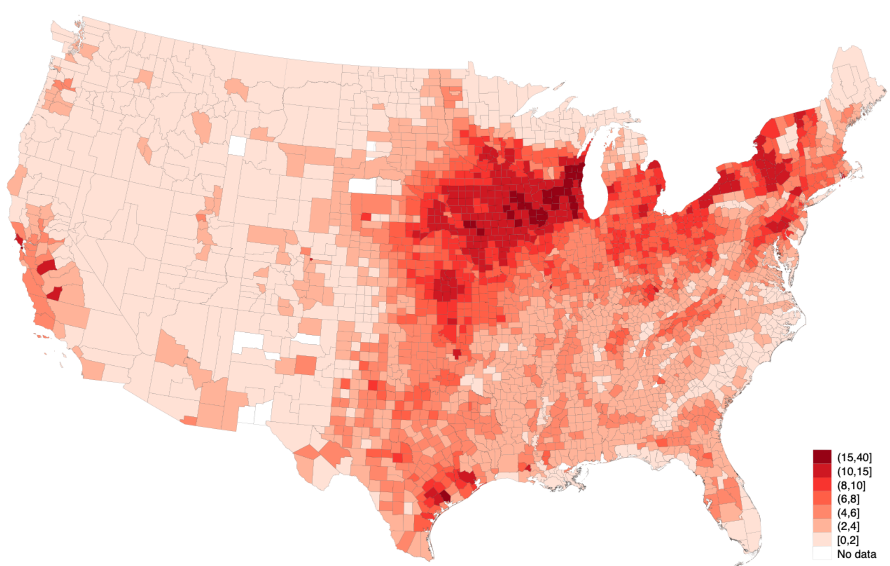
[5] Appendix Figure 6 shows the specialized rail cars and ice manufacturing facilities along the rail lines.

(Federal Trade Commission, 1919). Refrigerated beef production was highly concentrated both across and within stockyard markets: the ten largest stockyard markets contributed to almost 80% of all cattle slaughtered for interstate trade, with Chicago alone producing nearly a quarter of the cattle. Within each market, the Big Five accounted for almost all cattle slaughtered at the stockyards (see Appendix Table 1), and because they dominated the cattle purchase and refrigerated beef production, the Big Five naturally dominated the downstream beef wholesale market. By 1903, the packers furnished 75% of all beef consumed in New York City, 85% in Boston, 60% in Philadelphia, and 95% in Providence (Bureau of Corporations, 1905).

2.2 Cattle Production and the Stockyard Spot Market

Cattle production was concentrated in the Midwest in the early twentieth century. Figure 1 displays the spatial distribution of cattle in 1910. Illinois, Wisconsin, Iowa, and Kansas had the highest cattle density. Feedlot farmers fattened cattle with corn and hay for three to six months, then shipped and sold their cattle at the stockyard spot markets. About 85% of cattle shipped to the Chicago stockyards were fattened on small feedlots in the "Corn Belt" of the Midwest (Clemen, 1923). Proximity to stockyards allowed cattlemen to respond quickly to price fluctuations when making their shipment decisions. For example, in a 1905 report, the Bureau of Corporations noted that "there is always a large potential supply of cattle ready or nearly ready for market compared with the amount actually shipped [...] and a large number, therefore, can be rushed to market at a day's notice if the prices are sufficiently attractive" (Bureau of Corporations, 1905).

Figure 1: Cattle Density (per hundred acres), 1910

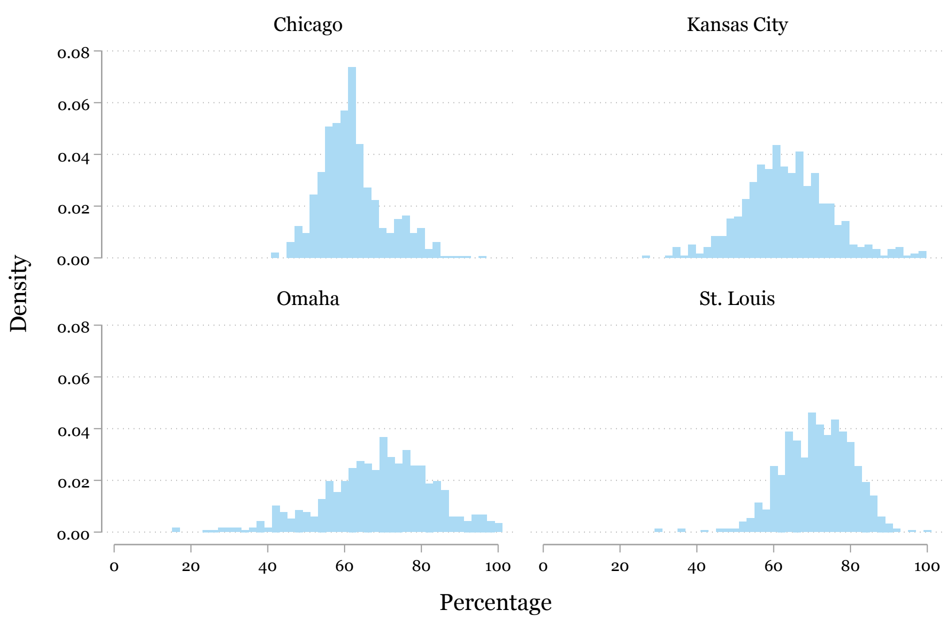


Notes: Data from the 1910 Census of Agriculture (Haines et al., 2018). Values exclude milk cows and working oxen. The data are plotted with 1910 county boundaries.

The stockyard markets opened six days a week and were closed on Sundays. Stockyards charged sellers for feeding, watering, and storing the cattle. Thus, most sellers would only stay on the stockyard for a day or two, either making a sale on the stockyard market or leaving for an outside buyer (Specht, 2019). The stockyard markets were composed of a large number of small price-taking sellers and the monopsonistic meatpacking cartel. Chicago's Union Stock Yards, for example, received, on average, more than 9,000 cattle per day. The total number of cattle available for sale on the market dwarfed the capacity of any individual seller. Further, the high cost to ship live cattle led to inelastic supply decisions on the spot market. For example, in 1908, it cost between $4.43 and $8.03 to ship a steer from a feedlot in Kansas to Chicago (Andrews, 1908).[6] Meanwhile the average profit per head was $12.79 for the same year (Skinner, 1909). Therefore, cattlemen were reluctant to take their cattle off the market once they arrived at the stockyards.

There was a large alternative market for live cattle beyond the stockyards. Figure 2 plots the distribution of the share of cattle in stockyards purchased by the cartel. On average, 15% of the cattle shipped to the stockyards were not sold on the spot market and were sold in the outside market to small retail butchers. In 1909, slaughtering and meatpacking establishments processed 59.6% of all cattle slaughtered for food in the United States (1909 Census of Manufactures). The rest were processed on the farm or in retail slaughterhouses.[7]

Figure 2: Percentage of Cattle Purchased by the Big Five at Stockyard



Notes: Data are from *The National Provisioner*.

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

[7]Cities closer to the Corn Belt, such as Cleveland, Cincinnati, and Indianapolis, relied more on local slaughter for fresh, unrefrigerated beef. In these cities, packers contributed less than a third of the fresh beef supply (Bureau of Corporations, 1905).

Cattlemen had long complained about the large supply and price variations at stockyard markets, and they attributed the fluctuations primarily to the meatpackers that dominated the stockyard markets. For example, the National Live Stock Association president highlighted the frustration against the packers 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, creating a glut one week and a famine the next" (American National Live Stock Association, 1909). Nevertheless, without the cattle futures market, which was not introduced to the Chicago Mercantile Exchange until 1964, cattlemen lacked the financial tools necessary to hedge against price fluctuations.

The spot market trading environment was conducive to collusion among the meatpackers. The meatpackers purchased cattle in the open market and immediately shipped the cattle to their packing plants adjacent to the stockyard for processing (see Appendix Figure 8 and Appendix Figure 9). Thus, the packers could directly observe other buyers' realized quantity and prices. In other words, cartel members could easily monitor compliance with their collusive agreements 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 7). There was little productivity difference across firms as they draw 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% of total production cost in the slaughtering and meatpacking sector, while non-fuel materials, primarily livestock, accounted for 90.7% of production cost. 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 Manipulation

3.1 Cartel History and Strategy

Between 1893 and 1918, the cartel controlled both the live cattle market and the wholesale beef market. However, legal challenges forced the meatpacking cartel to switch its monopsony strategy in 1913. Therefore, I divide the cartel strategy into the two phases, before and after 1913.

Before 1913: Cartel Manipulation Since 1893, the packers blatantly colluded by meeting "every Tuesday afternoon at 2 o'clock" in Chicago to discuss cartel strategies (Federal Trade Commission, 1919). They formed a joint holding company as a legal cover, and the packers met every week in the name of the "board meeting" of the holding company.[8]

Cartel members used the weekly meeting to manipulate the market prices signals. Because cattlemen made shipment decisions based on the most recent stockyard prices, the cartel used their market power to manipulate prices from week to week to induce large shipments to the stockyard and then exploited the inelastic spot-market supply. Circuit Judge Peter Grosscup best summarizes the strategy when granting the injunction against the packers in 1903 (*United States v. Swift & Co.* 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. [emphasis added]

In 1905, in a unanimous decision, the U.S. Supreme Court upheld the lower court's ruling in the aforementioned case. It affirmed the injunction against the packers (*Swift & Co. v. United States*, 196 U.S. 375)[9]. In the majority opinion, Justice Oliver Wendell Holmes summarized the cartel manipulation strategy in a similar way:

> 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. [emphasis added]

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

In addition, while the court issued and upheld injunctions against the packers' collusion, both the lower court and the supreme court's decisions included specific qualifications that "nothing

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

[9] The Attorney General, Henry Moody, who successfully argued this case against the packers 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 legal challenges against the packers.

[11] *The New York Times*, March 21, 1906.

[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)

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, provided no explicit threat to the continued operation of the cartel. Packers continued to meet every week to discuss market strategies despite repeated legal challenges.

After 1913: Standard Monopsony The Justice Department brought a new criminal case against the packers, which went to trial in 1912. Evidence admitted by the court includes 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, during deliberation, the jurors "did not review the exhibits ", claiming that "the mass of figures and reports mystified them."[15] 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 evidence presented in court, "the proof was so strong and conclusive that the packers did not wish to run the risk of another trial" for a civil case. The Department of Justice announced that they would file a civil case against the packers unless they dissolve the holding company where they meet as "board members".[16] The packers quickly acquiesced.[17] By the end of January 1913, the packers finalized the dissolution and suspended the weekly meetings (Federal Trade Commission, 1919).

After January 1913, when the packers dissolved the joint holding company and suspended the weekly "board meetings", they could no longer coordinate to manipulate the price signals. Instead, the packers resorted to the standard monopsony strategy in the cattle wholesale market: they maintained fixed market shares while collectively purchasing at the same monopsony price level.[18]

3.2 Cartel Members Did Not Deviate

One obvious concern is that, without the weekly meeting, cartel members may deviate 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, therefore, may have caused potential deviation from the collusive agreement

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

[14] *The National Provisioner*, March 9, 1912.

[15] *The New York Times*, March 27, 1912.

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

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

[18] The Federal Trade Commission later found that, to maintain the relative market share, the cartel would divide the shipment from individual sellers at a constant ratio.Federal Trade Commission (1919), volume 2 section 7.

Figure 3: Cartel Members Did Not Deviate

Notes: The graph plots the market share of each packer as a percentage of total cartel purchases. The 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 the packers across all four stockyards.

and thus would not match 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. Cartel members can directly observed the realized quantity and prices of every firm. Thus, even without the weekly meeting, the stockyard environment made it hard for cartel members to secretly deviate from the collusive agreement.

Market data provide empirical support for this claim. Figure 3 shows the aggregate market share for each packer after 1913. Relative market share among the cartel members remained stable, suggesting cartel members did not deviate from their collusive market share agreement after suspending the weekly meetings. Note that the packers colluded in *all* stockyard markets to maintain constant relative market share in total quantity purchased. However, limited by data, I only calculated the relative market share using the quantity from the top four stockyards, which can explain some of the variations from week to week.

The Federal Trade Commission also found evidence of stable market share among the packers in other stockyard markets during the non-manipulation period. The FTC uncovered internal documents from the packers for 1916 and 1917, showing that they observed and recorded each others' market behaviors to monitor compliance. The FTC found that the packers 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 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).

4 Model

I use a stylized two-period game to model the manipulation strategy described above. The results show that the manipulation can be sustained in equilibrium even when sellers know the signals are not always truthful.

4.1 Setup and Timeline

Consider a unit measure of sellers, $\theta \in [0,1]$, who can sell either to the cartel at the stockyard market or to a competitive outside market. Sellers are ordered so that larger θ represents sellers further from the stockyard market. The cartel privately observes the demand state $\omega \in \Omega$ for beef in urban markets. Sellers do not observe the state but share the common i.i.d prior about the true state $\rho(\omega)$. Both sellers' and cartel's payoff depend on the state ω and sellers' actions in the two periods $\mathbf{a} = (a_0, a_1)$.

At $T = 0$, the cartel privately observes the demand state ω, and sends a (costly) signal $s \in S$ to sellers, following a strategy $\sigma : \Omega \to S$, where $\sigma(s|\omega)$ is the probability of sending signal s after observing state ω. Sellers observe the signal s and update the posterior belief on the state, $\beta(\omega|s)$.[19] Given the posterior beliefs, sellers choose between shipping to the stockyard and selling to the outside competitive market at p_0. Let a_0 denote sellers' action at $T = 0$. If they choose to ship to the stockyard, they will incur a shipping cost of $m(\theta)$. Shipping cost increases in type θ (distances from the market), or $m'(\theta) > 0$.

At $T = 1$, sellers arrive at the stockyard. The cartel sets the monopsony market price p_c. Sellers can either accept the cartel price or leave the stockyard to sell to the outside market. Let a_1 denote sellers' action at $T = 1$. If they choose to leave the stockyard, they will receive $v(\theta)$. I assume the payoff from leaving the market decreases in θ, or $v'(\theta) < 0$, so sellers further from the market have lower outside values once they arrive at the stockyard.[20] Cartel acquires cattle from the fraction of sellers willing to accept p_c and produces refrigerated beef for urban consumers for profit.

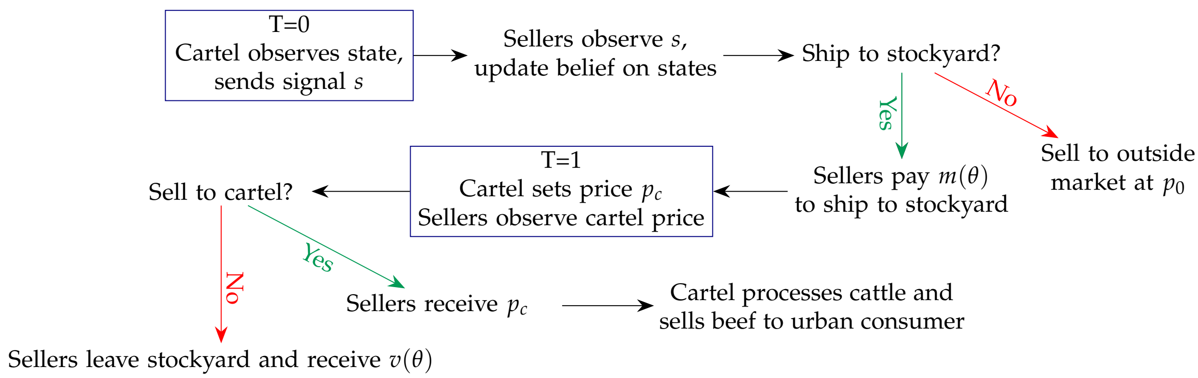
I summarize the timeline of the game in Figure 4 below. Note that while the setting is reminiscent of the hold-up problem, the structure and implications differ. Unlike the the hold-up problem in which investment is relationship-specific and has no outside value, in the case of the cattle market, the sellers can always sell to the outside market, even after making the sunk cost to ship to the stockyards. In addition, the typical hold-up problem considers a single unit for

[19] The posterior belief is given by the Bayes' Rule, $\beta(\omega|s) = \frac{\sigma(s|\omega)\rho(\omega)}{\int_{\omega' \in \Omega} \sigma(s|\omega')\rho(\omega')d\omega}$

[20] One can interpret $v(\theta)$ as the competitive price a seller can receive from the outside market p_0, minus the cost of shipping from the stockyard to the outside buyer. While the competitive market price is the same for all sellers, the cost to leave the stockyard and find the next buyer depends on sellers' types. Similar to $m(.)$, I assume this cost to increase in θ. Intuitively, sellers further from the market would have less connection or knowledge of the outside market near the stockyard, or alternatively, it will cost them more to bring the cattle back to their farm to wait.

sale. However, for the monopsony cartel, because sellers have outside options, in order to acquire more cattle under a high demand state, the cartel will have to increase the price offered at the stockyard. Thus, unlike the hold-up problem, the cartel cannot appropriate all the gains from the sunk investment.

Figure 4: Model Timeline



Notes: This figure provides an overview of the model. The two blue boxes indicate cartel's choices. The two sets of colored arrows labeled with "Yes" and "No" indicates sellers' choices. $m'(\theta) > 0$, $v'(\theta) < 0$.

4.2 Sellers' Problem

Second Stage Consider sellers already at the stockyard at $T = 1$. The cost from farm to stockyard, $m(\theta)$, is sunk and does not affect the choices at this stage. Sellers choose between selling to the cartel at the stockyard, or leaving and sell to the outside market. Let $a_1 \in \{0, 1\}$ represents the choice between the stockyard or the outside market. In the second stage, sellers' problem is:

$$\max_{a_1(\theta, p_c)} \underbrace{a_1 p_c}_{\text{sell to cartel}} + \underbrace{(1 - a_1)v(\theta)}_{\text{sell to outside market}}$$

Sellers already at the stockyard would accept the cartel price if $p_c \geq v(\theta)$. Because $v(\theta)$ decreases in θ, sellers' decisions follow the cutoff rule:

$$a_1^*(\theta, p_c) = \begin{cases} 1 & \theta \geq \underline{\theta}, \text{ "sell to cartel"} \\ 0 & \theta < \underline{\theta}, \text{ "leave stockyard"} \end{cases} \tag{1}$$

where $\underline{\theta} = v^{-1}(p_c)$. The optimal strategy at the stockyard means that sellers above the threshold type $\underline{\theta}$ (i.e. low outside value) would be forced to sell to the cartel once they arrived at the market. Meanwhile, sellers with higher outside values $v(\theta)$ can afford to reject the cartel's price and sell to the outside market. $v(.)$ decreases in θ, meaning sellers further from the market were at a greater disadvantage while sellers nearby were less affected by a disappointing cartel price. Define $F(\theta) = v^{-1}(\theta)$, so $F(.)$ maps the cartel price to the upper bound of seller types that would leave and sell to the outside market.

First Stage At $T = 0$, seller θ observes signal s and chooses between the outside and the stockyard markets to maximize the payoff. If a seller decides to ship to the stockyards, he pays the shipping cost $m(\theta)$ but may either sell to the cartel or leave for the outside market after arriving at the market at $T = 1$. Therefore, the expected payoff from shipping to the stockyard market in the first stage contains three parts: (1) the expected payoff if he sells to the cartel, (2) the expected payoff if he leaves the stockyard and sells to the outside market, (3) shipping cost. Let $\mathbb{E}[U_{ship}(\theta, s)]$ denote the expected payoff of shipping to the stockyard at $T = 0$, where

$$\mathbb{E}[U_{ship}(\theta, s)] = \Bigg(\underbrace{\int_{\omega \geq p_c^{-1}(v(\theta))} \beta(\omega|s) p_c d\omega}_{\text{sell to cartel}} + \underbrace{v(\theta) \int_{\omega < p_c^{-1}(v(\theta))} \beta(\omega|s) d\omega}_{\text{payoff if leave stockyard}} \Bigg) - \underbrace{m(\theta)}_{\text{shipping cost}} \tag{2}$$

Proposition 1. For any signal s, $\mathbb{E}[U_{ship}(\theta, s)]$ is monotonically decreasing in θ

See proof in Appendix B

Let action $a_0 \in \{0, 1\}$, denote the sellers' shipment decision. Sellers would ship to the stockyard if the expected return from shipping to the market is higher than that of the outside market, or $\mathbb{E}[U_{ship}(\theta, s)] \geq p_0$. Sellers' problem in the first stage can be expressed as

$$\max_{a_0(\theta, s; p_0)} \underbrace{\Big(a_0(\mathbb{E}[U_{ship}(\theta, s)]) \Big)}_{\text{ship to stockyard}} + \underbrace{\Big((1 - a_0) p_0 \Big)}_{\substack{\text{not ship to stockyard} \\ \text{sell to outside market}}} .$$

Because $\mathbb{E}[U_{ship}(\theta, s)]$ is monotonically decreasing in θ, there exists a unique $\bar{\theta}$ such that $\mathbb{E}[U_{ship}(\bar{\theta}, s)] = p_0$, and for any $\theta' > \bar{\theta}$, $\mathbb{E}[U_{ship}(\theta', s)] < p_0$.

Intuitively, suppose type $\bar{\theta}$ is indifferent between shipping to the stockyard and not at $T = 0$. Any other seller with $\theta' > \bar{\theta}$, who faces higher shipping cost $m(\theta') > m(\theta)$ and lower outside value $v(\theta') < v(\bar{\theta})$, should expect lower return from shipping to the stockyard than $\bar{\theta}$. Therefore, sellers' optimal strategy in the first stage also follows a cutoff rule:

$$a_0^*(\theta, s; p_0) = \begin{cases} 1 & \text{if } \theta \leq \bar{\theta}, \text{ ``ship to stockyard''} \\ 0 & \text{otherwise, ``ship to outside market''} \end{cases} \tag{3}$$

Define $G(\theta)$ as the density function that maps the expected payoff to seller type that would ship to the stockyard in the first stage. We can now write the total number of cattle purchased by the cartel, q_c, in terms of signal strategy $\sigma(s|\omega)$ and cartel price p_c:

$$q_c(\sigma(s|\omega), p_c; p_0) = \underbrace{G\big(\beta(\omega|s), p_c; p_0\big)}_{\text{ship to stockyard}} - \underbrace{F\big(p_c\big)}_{\text{leave stockyard}} \tag{4}$$

where $G(.)$ represents the fraction of sellers willing to ship to the stockyard market. Similarly,

$F(.)$ represents the fraction of sellers who arrived at the stockyard but, after observing the cartel price, decided to leave. The difference between the two is the quantity acquired by the cartel.

4.3 Cartel's Problem

Cartel chooses the signal and pricing strategies, $\sigma(.)$ and p_c, to maximize profits. At $T = 0$, after observing the demand state ω, the cartel chooses the strategy $\sigma : \Omega \to S$ that generates the signal for the sellers, which influenced the total number of cattle shipped to the stockyards, given sellers' beliefs $\beta(\omega|s)$ and strategy $a_0(\theta, s)$. At $T = 1$, the cartel chooses the price p_c at the stockyard markets, which determines the number of cattle leaving the market, given sellers' strategy $a_1(\theta, p_c)$. For any observed state ω, cartel's signals and prices pin down the quantity the cartel can acquire from the market, thus the profit $\pi(p_c, \sigma(s|\omega); \omega)$. The cartel's profits across all the states is

$$\max_{\sigma(.),p_c} \int_{\omega\in\Omega} \rho(\omega)\sigma(s|\omega)\Bigg(\pi(p_c,\sigma(s|\omega);\omega) - K(s,\omega)d\omega\Bigg) \tag{5}$$

$K(s, \omega)$ is the potential cost of sending the signal s. Following Kartik (2009), I assume the cost is convex in the signal, so the "further" the signal is from the state, the larger the cost.[21]

Equilibrium The subgame perfect Nash equilibrium consists of:

1. sellers' posterior beliefs $\beta(.)$
2. sellers' actions $\mathbf{a} = (a_0, a_1)$
3. cartel's price p_c and signal strategy $\sigma(.)$

Sellers' posterior beliefs follow Bayes' rule; sellers choose the optimal actions $\mathbf{a}^*$, given cartel's equilibrium signal and pricing strategy. Cartel's optimal price p_c^* and signal strategy $\sigma^*(.)$ maximize the profit in (5), given sellers' beliefs and equilibrium actions.[22]

4.4 How Do Signals Affect Shipment to Market

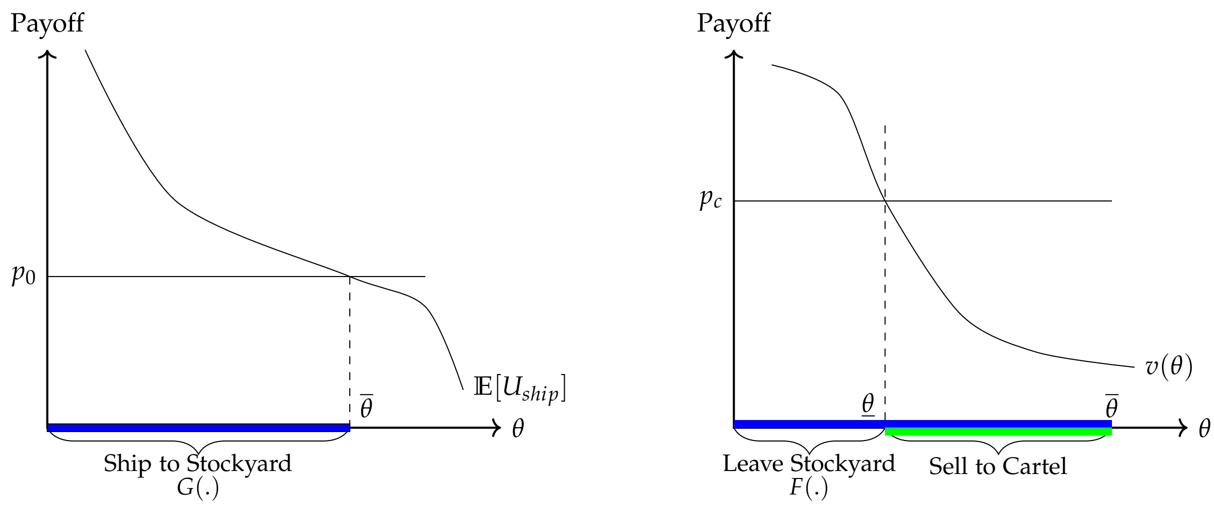
Cartel's signals affect the stockyard market by shifting sellers' expectations on the state. In panel (a) of Figure 5, the blue segment represents the seller willing to ship to the stockyard after observing s. By sending a "high" signal at $T = 0$, the cartel increased sellers' posterior belief $\beta(\omega|s)$ on high demand states, which in turn increases the expected payoff from shipping to the stockyard.

[21] Intuitively, because the signals include the price the cartel paid at the market and potential paid editorial or news coverage, the marginal cost of such actions increases as the signal moves further from the actual state.

[22] Kartik (2009) and Nguyen and Tan (2021) show that there exists a perfect Perfect Bayesian Nash Equilibrium where the signal sender (cartel) would "inflate the language" and claim to be in the higher state, while the receiver (sellers) are willing to follow the signals, knowing that they do not always reflect the true states ω.

These sellers with higher costs, who would not have shipped to the market without the high signal, are also less likely to leave the stockyard in the second stage after observing a low cartel price. Panel (b) of Figure 5 reflects sellers' decision after arriving at the stockyard, described in equation (1). At $T = 1$, the cartel sets the price p_c at the stockyard. Equation (1) shows that p_c determines $\underline{\theta}$, the highest type θ that would *leave* the stockyard. Sellers who shipped to the market but did not leave, highlighted in green in panel (b), corresponds to the quantity the cartel can acquire at price p_c.

Figure 5: Sellers' Choices in Two Stages



(a) T=0 (b) T=1

Notes: The figures shows the relationship between payoffs and sellers' choices in the two stages. The left panel represents the sellers' decision at $T = 0$, choosing between selling to the outside market at p_0 and shipping to stockyard market for $\mathbb{E}[U_{ship}(\theta, s)]$. The right panel represents sellers' choice at $T = 1$, between selling to the cartel at the market price p_c and leaving the stockyard to sell to the outside market, where the payoff $v(\theta)$ decreases in sellers' types.

Cartel's signal and price strategies affect the cattle shipment and sales at the stockyard through the two steps. First, by manipulating the market signal, the cartel increases $\bar{\theta}$ and attracted sellers with higher shipping costs. Then, cartel can lower the price p_c at the market and acquire cattle from sellers who cannot afford to leave the stockyard.

It is worth noting that the model assumes rational sellers with Bayesian beliefs. This implies that the cartel can manipulate sellers repeatedly, even when the sellers *know* that the signals were not always truthful. For example, suppose nature draws from a binary state $\omega \in \{H, L\}$ with probability $\rho(H) = 0.3, \rho(L) = 0.7$. Cartel observes the states, sent signal $s \in \{h, l\}$ such that (1) the signal is always truthful in H state, and (2) cartel lies in L state, with $\sigma(h|L) = \frac{3}{7}, \sigma(l|L) = \frac{4}{7}$. This leads the seller to increase the posterior belief of H state given a h signal to 50%, even though sellers know that only 30% of the time the market would be in the H state, and the h signal can be a lie.[23]

[23]Example adapted from Kamenica and Gentzkow (2011).

4.5 Gap between Model and Data

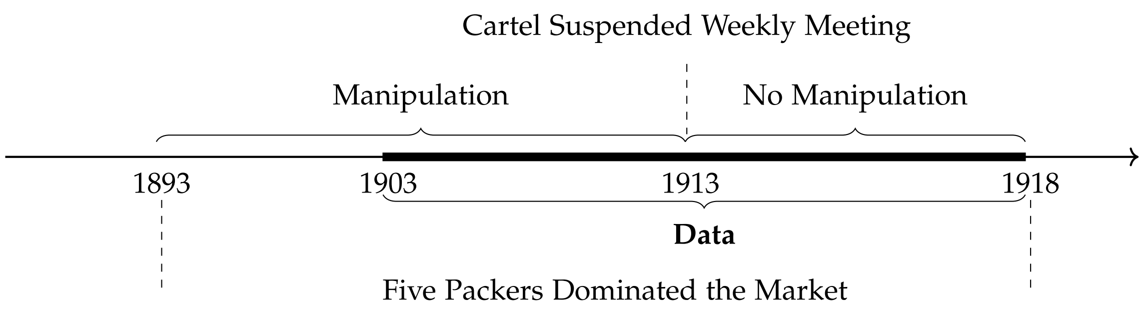
While this stylized model supports the claims documented in the legal cases that the cartel successfully manipulated the cattle wholesale market price signals, the model cannot be directly estimated due to data availability. Specifically, the equilibrium strategy and market outcome are determined by two factors: (1) the distribution of states ω, and (2) the distribution of the shipping costs, $F(.)$ and $G(.)$. However, neither is directly observed in the data.

The historical setting allows me to analyze the effect of cartel manipulation without estimating the parameters of the game under manipulation. Because I observe the market outcomes with and without the cartel manipulation, I can directly construct the counterfactuals for the manipulation period and compare the observed market outcomes with the model baseline. The result quantifies the empirical damage created by the cartel manipulation while allowing for imperfect collusion or non-optimal strategies (i.e., allowing the cartel to deviate from the optimal solutions due to unobserved institutional frictions.).

5 Data

I collected weekly livestock market data from historical trade journals and stockyard annual reports to quantify the effect of the cartel manipulation. These data cover the four largest stockyards from 1903 to 1917. Figure 6 shows where the data lie on the overall time frame. Because the cartel was forced to suspend the market signal manipulation in 1913, I can directly observe the market outcomes with the same cartel, market concentration, and production technology but under different collusive strategies. I combined this livestock market data with information on input cost and downstream sales to analyze the decisions of both the cattlemen and the cartel.

Figure 6: Event Timeline and Data Coverage



5.1 Livestock Market Data

I compiled weekly price and quantity data from 1903 to 1917 for the four largest stockyards: Chicago, Kansas City, Omaha, and St. Louis. The four markets collectively processed more than

53% of cattle slaughtered for interstate trade in 1916 (Federal Trade Commission, 1919).[24] Market information, including the number of cattle shipped into the stockyards, realized market prices, and the number of cattle purchased at the stockyard or left for the outside market, were widely published. To compile a complete set of weekly data on price and quantity, collected market information from three trade journals *The National Provisioner*, *The Drover's Journal*, and *Nebraska Bee*. I also digitized official annual reports from the Chicago Union Stockyard Company, Chicago Board of Trade, and the Merchants' Exchange of St. Louis. Appendix C provides details on variable construction and validation.

Table 1 provides the stockyard markets' summary statistics. On average, more than 9,000 head of cattle a day were shipped to Chicago's Union Stock Yards, 60% of which were purchased in transactions valued at $1 million. The other three stockyards operated on a smaller scale but were all dominated by the same packers.

Table 1: Summary Statistics

	(1) Chicago	(2) Kansas City	(3) Omaha	(4) St. Louis	(5) Total
Cattle Price in 1920$	17.12	16.45	16.32	18.51	16.80
	(2.63)	(2.62)	(2.44)	(1.79)	(2.59)
Daily Average Shipment (000s)	9.36	6.78	3.46	3.50	6.58
	(2.27)	(2.72)	(1.29)	(1.47)	(3.27)
Daily Average Cartel Purchase (000s)	5.52	4.16	2.18	2.48	4.00
	(1.44)	(1.46)	(0.68)	(1.13)	(1.86)

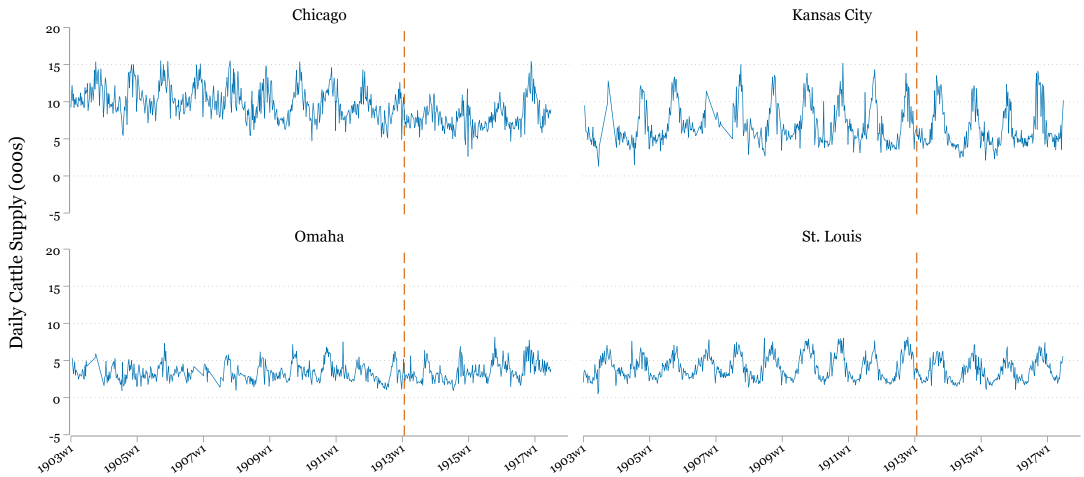
Note: Price and quantity data are from *The National Provisioner*.

Cattle supply exhibits significant variations from week to week. Figure 7(a) shows the average daily shipment for each stockyard. The cattle supply exhibits apparent seasonality, driven by the natural production cycle of cattle. However, even within a short period, the total number of cattle arriving at the stockyard can also change dramatically. 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. As an example, I display the weekly fluctuations for a short time frame (1909-1910) in Figure 7(b). The average change is $\pm$ 17%, and in one out of three weeks, the shipment deviated by more than 20%.

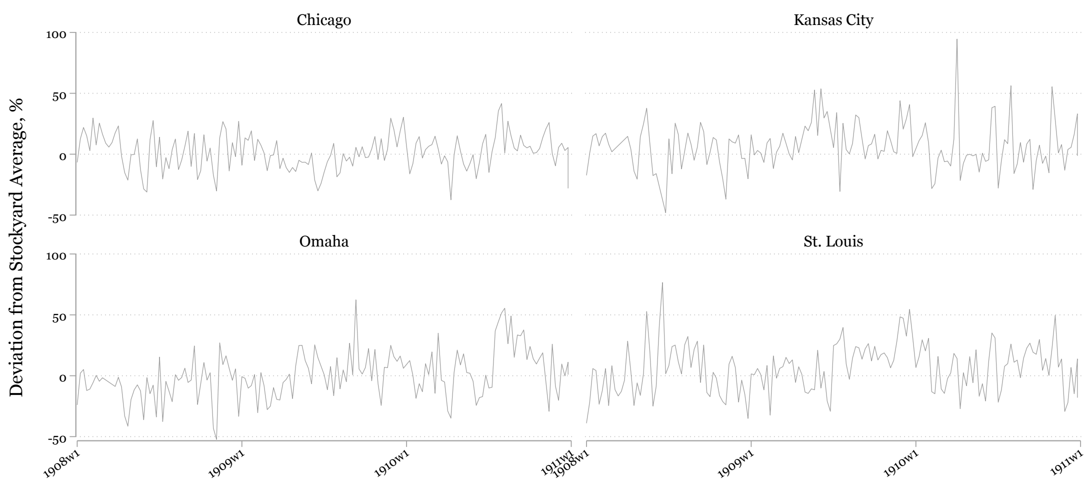
[24] The distribution of the market sizes is very skewed. In 1916, nearly 2 million heads of cattle were slaughtered in Chicago, while in New York, the fifth largest market, only 0.4 million heads were slaughtered. (Federal Trade Commission, 1919)

Figure 7: Cattle Shipment and Prices

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



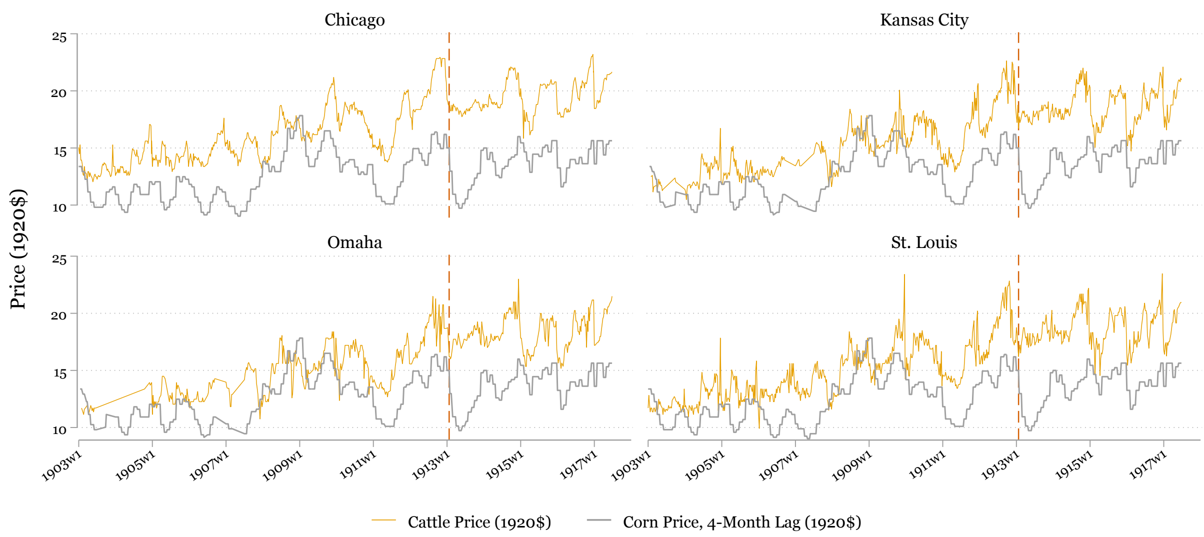
(b) Example of Deviation from Week-of-Year Average
1908-1910



Notes: Deviation is the percentage difference between the shipment and the week-of-year averages, where the week-of-year average shipment value is calculated separately for each stockyard using data from 1903 to 1917.

In Figure 8, I plot the weekly cattle price and the 4-month lagged wholesale corn prices. Some price changes can be attributed to the shifts in cattle production costs. However, the profit margin for cattle sellers, approximately the difference between cattle and corn prices, were different over time. In particular, the gap grew larger after 1913, when the cartel stopped manipulating the signal. As suggested by the model in section 4, market prices would increase without

Figure 8: Cattle Price by Stockyards



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

manipulation, which coincides with the larger gaps in the price data. Spot market prices also varied dramatically from week to week. As a benchmark, the average profit margin for the standard 1,200lb cattle is $12.79 in 1909 (Skinner, 1909). Thus, a $0.25 drop in the wholesale price would wipe out 30% of a cattleman's net profit.

Notably, the spot market prices across different markets were highly correlated, with and without cartel manipulation. Two factors drove this. First, the price fluctuation reflected common changes in cattle production costs. As discussed in section 2.2, the primary suppliers to the market are small feedlot farmers on the Great Plains. Weather, particularly drought and winter storms, and fluctuations in corn and hay prices were likely to be correlated for farmers in this region. Second, the cartel tried to avoid arbitrage across markets by ensuring that the prices of any stockyards were "in line" with the other markets (Federal Trade Commission, 1919). [25] Therefore, the prices across stockyards are highly correlated despite being distant from each other.

5.2 Auxiliary Data

I collected weekly wholesale prices of live hogs in New York City from the *The National Provisioner*. Live hogs were a close substitute for refrigerated beef and were not influenced by the

[25] A seller might not be satisfied with the price at the first market and would try to ship the cattle to another stockyard. In some cases, a seller may also divide 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 the seller would receive the same price at different locations. As a result, such practice was infrequent. See Federal Trade Commission (1919) volume 2 section 8 for examples of the telegrams.

cartel.[26] The wholesale price of live hogs in the downstream urban market capture week-to-week consumer demand fluctuations faced by the cartel. Such prices would influence the cartel's demand on the cattle market, and therefore I use them as instrumental variables to estimate the supply parameters.

The main factors affecting cattle production were feed cost and weather. I collected monthly wholesale corn and hay prices from the *Chicago Board of Trade Annual Report* and the *Department of Agriculture Yearbook*.[27] To measure weather shocks, I construct monthly average and extreme values of temperature and precipitation using the county-level historical weather data from Bleakley and Hong (2017). [28]

In addition, to estimate the retail demand for beef and other food items, I used the 1917–1919 cost of living survey,[29] which is one of the earliest household consumption and expenditure surveys. It provides detailed household expenditure data on 12,817 families of wage earners or salaried workers in 99 U.S. cities, coinciding with the type of urban markets served by the cartel. In section 8.2, I discuss how I constructed the data for demand estimation.

6 Descriptive Evidence of the Cartel Manipulation Strategy

In this section, I provide reduced-form evidence on the effects of the cartel manipulation strategy on the cattle wholesale market. To do so, I first compare the aggregate market outcomes with and without manipulation. I then show that consistent with narrative evidence and model predictions, the cartel successfully manipulated cattlemen's actions with misleading price signals.

6.1 Cartel Manipulation is Effective

I first use an event study design to examine how the changes in cartel strategies influence aggregate market outcomes. Antitrust enforcement forced the cartel to adjust its market strategy while other aspects of the market remained unchanged. It is thus plausible to attribute the difference in aggregate outcomes to the changes in the cartel strategy.

Specifically, I estimate the following regression

$$y_{kt} = \alpha \mathbb{1}(\text{Manipulation}_{1903-1912}) + X_t + K_{kt} + \eta_{kw} + T + \epsilon_{kt} \tag{6}$$

y_{kt} is the aggregate market outcome variable for stockyard k at time t. α is the event study coefficient representing the average difference of the outcome y_{kt} with and without cartel manip-

[26] The cartel also produced cured meats and refrigerated (dressed) lamb, pork, etc. Though these animal products are close substitutes, their prices cannot be a plausible instrument.

[27] Specifically, I use the No. 2 corn from Chicago Board of Trade (various years) and No. 1 baled Timothy hay prices from Department of Agriculture (various years).

[28] The average temperature and precipitation are weighted by county areas. The sample includes only the non-coastal states where the weather conditions were relevant for cattle production. This excludes the states in the New England, Middle Atlantic, South Atlantic, and Pacific census divisions.

[29] Bureau of Labor Statistics (1992). The data are digitized by the Inter-university Consortium for Political and Social Research (ICPSR) and are available as ICPSR study 8299.

ulation. The results controlled for shocks common to all markets, X_t. This 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 average, minimum, and maximum temperature and precipitation. The estimation also includes K_{kt}, the temperature and precipitation for the county where stockyard k is located. This represents weather shocks that may affect transportation conditions when the cattle were shipped to the market. η_{kw} is the stockyard-by-week-of-year fixed effect, which captures the seasonality of the cattle market at each stockyard; T is the yearly time trend.

The average market outcomes are consistent with the model predictions from section 4. Under cartel manipulation, 22% more cattle were shipped to the stockyards. The cartel price was 4.5% lower, while the total number of cattle purchased by the cartel remained at the same level. Finally, cattlemen's margin, defined as the difference between the wholesale cattle and lagged corn prices, was nearly 30% lower. Appendix Figure 1 provides an event-study version for equation (6) by estimating the coefficients for every calendar year. The results are consistent with the findings above: with signal manipulation, more cattle were shipped to the stockyard and sold at lower prices.

Table 2: Market Outcomes With and Without Cartel Manipulation

	(1) Total Shipment	(2) Price	(3) Cartel Quantity	(4) Cattlemen's Margin
Cartel Manipulation	1.148***	-0.849**	0.890	-1.530***
	(0.089)	(0.264)	(0.389)	(0.248)
Time Controls	Yes	Yes	Yes	Yes
Weather Controls	Yes	Yes	Yes	Yes
Cost Controls	Yes	Yes	Yes	No
Mean	5.33	18.75	3.55	5.11
% wrt Mean	21.52	4.53	25.07	29.97
Observations	2492	2369	2492	2369
Adjusted R-Squared	0.85	0.82	0.80	0.51

Note: "Cattlemen's Margin" is defined as the difference between cattle price and input cost, which is approximated by the four-month lagged corn price. Thus, the estimations for cattlemen's 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 stockyard. * $p < 0.10$ **, $p < 0.05$, *** $p < 0.01$

One concern for this event study is the effect of World War I. To avoid this influence, I use only the data from before April 1917, when the United States joined the war, for my main analyses. Though WWI may have spurred agricultural production even before then,[30] the competitive structure at the wholesale livestock market remained unchanged. Therefore, I assume the market

[30] Agricultural production increased steadily during the second half of the 1910s to satisfy robust export demand (Henderson et al., 2011).

behaved the same during this period. Any potential influence of the war on cattle production, especially through the prices of corn and hay, affected the cattle market in the same way as before through the cost channel. In addition, column (4) of Table 2 directly addresses the concern about rising price levels caused by the war. Though this is an event study, column (4) can also be seen as a difference-in-differences result, which compares the price of cattle with the price of corn and hay before and after the cartel meetings stopped. The result suggests that under cartel manipulation, cattle prices were lower compared to the price of corn and hay, which were traded in a competitive market throughout the whole period.

6.2 Cattlemen Behave Differently with and without Cartel Manipulation

As the model in section 4 suggests, the cartel manipulated sellers' belief on the market state. The manipulated signal may lead sellers to believe the market condition is better than the actual state. Because the weekly data contain both the total number of cattle shipped to the stockyards and the realized market price after their arrival, I can empirically document the cattlemen's behavioral responses under different cartel strategies.

I estimate the relationship between the total number of cattle that arrived at the stockyards and the realized market prices *after* the shipment decision were made, controlling for seasonality, production shocks, and general time trends:

$$p_{kt} = \beta Z_{kt} + X_t + K_{kt} + \eta_{kw} + T_y + \epsilon_{kt} \tag{7}$$

p_{kt} is the realized cattle price for the week t in stockyard k, Z_{kt} is the number of cattle arrived at the stockyard. T_y is the year fixed effect. This is different from (6), which includes only the linear trend T because the indicator variable for the manipulation period is also defined at the yearly level and thus cannot be identified with year fixed effects. Regression (7) does not have the manipulation dummy and thus can use the year fixed effects to better control for potential non-linear changes in the trend. All other variables are unchanged from equation (6).

β reflects the correlation between sellers' beliefs on the market price and the realized market prices. If sellers correctly predicted the market condition and shipped more cattle when the market price was high, one would expect β to be positive. Note that this is not a regression between price and quantity sold. As described in the two-stage game in 4.2, sellers made the shipment decisions *before* they observed the market price for the week. Furthermore, Z_{kt} is the number of cattle arrived at the market, not the number purchased by the cartel at p_{kt}.

Table 3 shows the estimation for β under different cartel strategies. The first two columns cover the manipulation period; the estimated coefficient suggests that the total number of cattle arriving at the stockyards during the manipulation period did not correlate with the realized market price. However, when the cartel stopped manipulating the price, more cattle were shipped to the stockyards when the realized price was high, as suggested by the positive and significant coefficient in columns (3) and (4).

I conduct two robustness checks to show that the results are not driven by learning or changes in the available market outlet. One concern is that cattlemen may have learned more about the market over time, implying that the estimation using the whole manipulation period may be biased. The second concern is that, because some cattlemen could choose between the stockyards, they may have behaved differently when multiple stockyards were closed (due to animal quarantine or extreme weather). Appendix Table 2 shows that cattlemen behaved the same in the first and second half of the manipulation period.[31] The results from the main specification in Table 3 are also robust to restricting the sample to cases with at least three operating stockyards.

Table 3: Price vs. Shipment

Dependant Variable: Price	Manipulation		No Manipulation	
	(1)	(2)	(3)	(4)
Daily Average Shipment (000s)	0.046	0.084	0.107**	0.130***
	(0.040)	(0.042)	(0.031)	(0.016)
Time Controls	Yes	Yes	Yes	Yes
Weather Controls	No	Yes	No	Yes
Cost Controls	No	Yes	No	Yes
Observations	1560	1560	807	807
Adjusted R-squared	0.78	0.81	0.61	0.72

Note: Standard errors are clustered by stockyard. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7 Analytical Framework of the Cattle Spot Market

This section presents a structural model of the cattle wholesale market under a monopsony cartel. The main goal is to quantify the effect of cartel manipulation by comparing the empirical outcomes with the counterfactuals under the standard monopsony strategy. Though the results from the event study provide an arguably causal estimate on the effect of the cartel manipulation strategy on input market price and quantity, the estimate provides only limited information on the underlying mechanism. In particular, it does not capture the counterfactual market outcome with both price and quantity changes, nor does it provide any information on the corresponding influence on welfare. Therefore, I develop the structural model to estimate what would happen during the manipulation period if the cartel adopted a standard monopsony strategy.

Because the cartel dominated both the input (i.e., cattle) and product (i.e., refrigerated beef) markets, the cartel faced an upward-sloping cattle supply and a downward-sloping beef demand. On the supply side, cattlemen make spot market sales decisions following a discrete choice model: cattlemen choose between selling to the cartel and selling to the competitive market outside of the stockyard.[32] I use the standard logit choice model to capture cattlemen's sales

[31] Given that the data cover the second half (1903–1912) of a two-decade-long manipulation scheme (1893–1912), this result is consistent with the assumption that the market should have arrived at an empirical equilibrium state after ten years.

[32] I assume the outside market to be perfectly competitive and thus do not consider the case of umbrella damage, where

decisions. On the demand side, I estimate the downstream demand that the cartel faces with the the AIDS model. I then combine the spot market supply and downstream retail demand to characterize the cartel's equilibrium strategy.

7.1 Cattlemen's Spot Market Supply

Following Berry (1994), I use a logit discrete choice model with differentiated buyers to capture cattlemen's spot market supply decisions. Cattleman i chooses between buyer j: $\mathcal{J} = \{\text{cartel, outside}\}$. As discussed in section 2.2, because of the high shipping cost, I assume that sellers cannot take the cattle off the market and have to sell to one of two buyers once they arrive at the stockyards.

The utility for cattleman i depends on price p_{jt}, cost factors $\boldsymbol{X_{jt}}$, latent buyer characteristics σ_{jt}, and an idiosyncratic utility shock ϵ_{ijt}. Cost factors $\boldsymbol{X_{jt}}$ include lagged weather and feed price shocks common to all cattlemen and stockyard-specific seasonality and weather conditions for time t. σ_{jt} represents unobserved (by econometrician) buyer characteristics, such as distance between the cattlemen and the buyer, or credit services provided by the buyer.[33] Finally, ϵ_{ijt} is a random utility shock identically and independently distributed across buyer-seller pairs and over time so that a seller may prefer a certain buyer today but this does not contain any information about the preference for the next period. This i.i.d assumption is reasonable for the non-manipulation period when both the cartel and cattlemen were making decisions to maximize the current-period gains and there was no long-term relationship between sellers and buyers. In other words, cattleman i's utility when selling to buyer j is

$$U_{ijt} = \gamma_p p_{jt} + \boldsymbol{X_{jt}}\gamma_x + \sigma_{jt} + \epsilon_{ijt}. \tag{8}$$

Suppose that ϵ_{ijt} follow an extreme-value type-I distribution and normalize the utility derived from the outside market to be zero. This generates the standard logit form of the market share expression

$$\ln(S_{cartel,t}) - \ln(S_{outside,t}) = \gamma_p p_{cartel,t} + \boldsymbol{X_{cartel,t}}\gamma_x + \sigma_{cartel,t}, \tag{9}$$

where $S_{cartel,t}$ is the share of cattle at the stockyard purchased by the cartel and $S_{outside,t}$ is the share of cattle that left the stockyard alive to be sold in an outside market. The supply side of the structural model characterized by (9) can be estimated using a simple instrument variable approach.

Of the Z_t cattle that arrived at the stockyard, the cartel can expect to purchase $q(p_{cartel,t})$ head at a given price $p_{cartel,t}$, where

the outside non-cartel buyers adjust their pricing to the supra-competitive level set by the cartel at the stockyard. This is plausible given the large number of small buyers outside the stockyard who compete in prices.

[33] For example, the meatpackers also operated cattle loan companies to provide credit for cattlemen to purchase calves and feed.

$$q(p_{cartel,t}) = \frac{\exp(\gamma_p p_{cartel,t} + \boldsymbol{X_{cartel,t}}\gamma_x + \sigma_{cartel,t})}{1 + \exp(\gamma_p p_{cartel,t} + \boldsymbol{X_{cartel,t}}\gamma_x + \sigma_{cartel,t})} Z_t. \tag{10}$$

7.2 Cartel's Demand

Based on the production process described in section 2.3, I use three main assumptions to simplify the cartel's demand. First, there is no substitution between cattle and other variable inputs. This implies that the cartel faces a Leontief production function. A packer uses q_t head of cattle and v_t units of other variable inputs to produce m_t units of refrigerated beef, or

$$m_t = \min\{\theta_1 q_t, \theta_2 v_t\}. \tag{11}$$

I further assume there is no productivity difference across firms. Because the production process relied primarily on manual labor and all the packers drew from the same local labor market, all firms likely share the same "conversion rate" between cattle and beef. In other words, all the cartel members share the same θ_1.[34] Finally, because cattle accounted for more than 90% of the variable cost, the analysis focuses only on the cost of cattle and abstracts away from all other costs such as labor or fuel. With these two assumptions, the cartel's production cost when purchasing cattle at p_t is

$$c(p_t) = m(p_t) \times p_t,$$

where $m(p_t) = \theta_1 q(p_t)$ and $q(.)$ is the inverse spot market supply function from (10).

Because the cartel is also a monopoly seller of refrigerated beef, it faces a downward-sloping demand curve $D(.)$. Therefore, the cartel chooses the optimal price p_t^* at the cattle wholesale market to maximize its profit:

$$p_t^* = \arg\max_{p_t} D(m(p_t))m(p_t) - c(p_t). \tag{12}$$

7.3 Equilibrium

With the cattlemen's supply decision and the cartel's profit function, I can specify the market equilibrium:

Definition 1. The spot market equilibrium is the set of price and cartel quantities $\{p_t^*, q_t^*\}$ such that the quantity corresponds to the expected spot market supply given by (10) and the price solves the cartel's profit-maximization problem in (12).

[34] For reference, a 1,200-pound steer yields a 750-pound carcass, or 63% of the input weight.

8 Identification and Estimation

I start by estimating the supply function and calculating the input-price markdowns of the spot market cattle supply under different cartel strategies. I then estimate the demand for refrigerated beef and construct the cartel's quantity decision given the cattle supply and beef demand. I use these results in the next section to simulate counterfactuals.

8.1 Spot Market Supply

As discussed in section 7.1, estimating spot market elasticity with observed market share and price data faces the typical simultaneity problem in industrial organization: the unobserved buyer characteristics σ_{jt} may influence both market price p_{jt} and demand. A demand shifter can be used as an instrument for cattle prices to identify the spot market supply function. Because the downstream demand for refrigerated beef influences the volume of cattle purchased by the cartel, I use the price of beef substitutes to instrument for the cattle price. Specifically, I use the lagged downstream wholesale price of live hogs as instruments for cattle prices at the stockyards.

Because the same cartel operated at all four markets, one may be concerned about the presence of correlations across markets and the serial correlation within a stockyard market. With such correlation, standard errors may be underestimated even with clustering. Instead, I used moving block bootstrap to calculate the standard errors while maintaining the correlation structures.[35]

Table 4 presents the estimated price coefficient γ_p, estimated separately for the manipulation and non-manipulation period. During the manipulation period, because the cartel was manipulating the wholesale prices as signals in anticipation of higher shipments next week, the model does not match the actual cartel pricing strategy. As expected, columns (1) and (2) show that that the estimated price coefficients are small and statistically insignificant under the manipulation strategy.[36] However, during the non-manipulation period, cartel behavior matched the standard monopsony model. After addressing the endogeneity issue with the instrument variable, column (4) shows that higher cattle prices indeed corresponded to a larger share of the total shipment bought by the cartel.

[35] Bertrand, Duflo, and Mullainathan (2004) suggest using block bootstrap by re-sampling the groups of observation when the number of groups is large, yet the data contain only four stockyards (i.e., "groups"). More importantly, this method assumes independence across groups, which is less likely to hold in this scenario when the same cartel is making purchasing decisions simultaneously for all four stockyards.

[36] This is driven by potential estimation bias for the manipulation period. As discussed in 6.2, because the cartel used market prices to manipulate the sellers from week to week, the residuals are likely to be correlated across time and thus violate the independence assumption for the estimation.

Table 4: Spot Market Supply

Dependent Variable: $\ln(S_{cartel,t}) - \ln(S_{outside,t})$	Manipulation		No Manipulation	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Cattle Price	-0.02	0.01	-0.04	0.13**
	(0.01)	(0.05)	(0.04)	(0.07)
Observations	1087	644	610	492
First-Stage F-statistics		40.32		39.31

Note: The table shows the regression coefficient γ_p described in equation (9). All estimations include the same set of time, weather, and cost controls. Standard errors are bootstrapped with 100 iterations. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The results highlight the importance of focusing the model estimation only on the non-manipulation period. Consistent with previous evidence that the cartel successfully manipulated the sellers, the insignificant results suggest that the market had a different data-generating process during the manipulation period. By modeling the market under the standard monopsony cartel strategy alone, this approach avoids specifying the complicated cartel manipulation while still providing a well-understood theoretical benchmark to quantify the effect of the cartel manipulation.

To interpret the results, I calculate the corresponding elasticity, markdown, and input share of revenue. Given the market share expression, the spot market price elasticity of cattle supply can be expressed as $e_s = \gamma_p p_{jt}(1 - S_{jt})$. Correspondingly, the cattle price markdown, ψ_s, can also be written as a function of price, market share, and the price coefficient, where $\psi_s = \big(\gamma_p p_{jt}(1 - S_{jt})\big)^{-1} + 1$. Input share of revenue is the inverse of markdown, or $\frac{1}{\psi_s}$. Since these statistics are non-linear in γ_p, I include the calculation of the three measures in the bootstrap process.

Table 5 presents selected moments for elasticity, markdown, and input share of revenue measures. The spot market supply is inelastic, with the average price elasticity of 0.94. This corresponds to the markdown value of 2.13, meaning cattlemen received 42% of their marginal contribution to manufacturing profits, on average. The results are consistent with the narrative evidence that the cartel had monopsony power on the cattle wholesale market.

Table 5: Elasticity, Markdown, and Input Share of Revenue

	Mean	SD	CI5	CI95
Elasticity	0.94	0.48	0.16	1.62
Markdown	2.13	1.37	1.51	3.98
Input Share of Revenue	0.42	0.35	0.14	0.62

Note: The table shows the estimated mean, standard deviation, and the 90% confidence intervals, calculated from the estimated regression coefficient γ_p described in equation (9). Results are bootstrapped with 100 iterations.

8.2 Cartel Demand

I estimate the demand for beef $D(.)$ separately using the AIDS model (Deaton and Muellbauer, 1980) and the 1917–1919 Cost of Living Survey (Bureau of Labor Statistics, 1992). The demand model corresponds to a two-stage budgeting process: at the higher level, households first choose to allocate expenditures across broad segments of food (meat, dairy, starch, vegetables). At the lower level, households allocate the expenditures for different products within the segment. In particular, given the expenditure on meat, a household may choose between beef, pork, poultry, and other meat products.[37] Appendix C reports the specific items included in each category.

This modeling choice is appropriate from both conceptual and practical perspectives. While discrete choice models were commonly used in demand estimation (Berry, 1994; Goldberg, 1995), the model assumptions do not match household food purchase behavior. Food items are different from durable goods such as cars or television: instead of choosing a single unit of one product out of all the alternatives, families purchase multiple units of food items from all the categories. Thus, the discrete choice model does not capture household food consumption decisions.[38]

In addition, the AIDS model provides demand elasticity estimates for broad categories, which is more relevant for the cartel's decision. As a wholesaler, the cartel cared about the overall demand for beef with respect to other food items such as pork. The AIDS model is a good first-order approximation for these broad product categories,[39] it provides the basis for evaluating the counterfactuals in the downstream product market. The demand estimation thus plays a part first in solving for the cartel's problem and later in calculating the welfare effects of the cartel manipulation on urban consumers.

The 1917 Cost of Living Survey covers 12,817 "families of wage earners or salaried workers" across 99 U.S. cities. The average household spent $544 a year on food, which accounted for 38.4% of its total annual expenditure. The four main segments used in the demand estimation contributed to 58.7% of the food budget. Beef dominated other meat products in terms of quantity: an average household consumed 168 pounds of beef per year, four times the quantity of pork.[40] Though the survey data contain household-level information, the reported prices on the household level exhibit little variation.[41] Therefore, for my analysis, I aggregate the data at the city level. The empirical environment restricts me from using other demand models that are feasible only with high-quality microdata. Appendix Table 3 summarizes the general household consumption pattern from the data.

[37] See Appendix D for details of the two-stage budgeting process for estimation.

[38] Though Björnerstedt and Verboven (2016) extends the nested logit model to allow consumers to choose multiple units, it still requires consumers to choose only one product out of all the alternatives.

[39] The quadratic extension of AIDS, or QUAIDS, has been used to fit household consumption data. However, as noted by Banks, Blundell, and Lewbel (1997), the original AIDS model has proven to be a good fit for food items.

[40] For comparison, in 2017, Americans consumed 54 pounds of beef per person, or 216 pounds of beef per year for a family of four. U.S. Department of Agriculture "Food Availability and Consumption" data series. Accessed on October 7, 2020.

[41] In many cases, the implied price of a particular product is identical across all households within a city, even when the families were asked about annual total cost and quantity on a particular product. This suggests that the surveyor may have imputed total cost or quantity variables using a fixed price.

Table 6 presents the summary statistics for price and expenditure share for the items I use in the estimation. Beef was the main source of meat consumption, contributing to half of the total household expenditure on meat products. Among the four food categories, households allocated 30% of their food expenditure to meat and dairy, 23% to starch (e.g., flour, rice, pasta), and 16% to vegetables (column (3)). Average prices from the survey are also comparable to values from contemporary market reports: for example, the wholesale price in New York City was 26 cents per pound for beef rib and 32 cents per pound for pork tenderloins.[42]

Table 6: Summary Statistics for Prices and Market Shares

	Price ($/lb)		Expenditure Share (%)	
	Mean (1)	SD (2)	Mean (3)	SD (4)
Meat Products				
Beef	0.29	0.04	50.53	7.56
Pork	0.36	0.08	15.50	6.08
Poultry	0.35	0.04	8.65	2.39
Other (fish, cured meat)	0.36	0.07	25.32	6.36
Food Segments				
Meat	0.31	0.03	30.02	3.65
Dairy	0.21	0.03	30.89	5.59
Starch	0.09	0.01	23.41	3.87
Vegetable	0.05	0.01	15.68	1.91

Note: Prices are aggregated up to the city level by expenditure share weight. The upper panel shows the prices and expenditure of the products under the "meat" segment; the lower panel shows the prices and expenditures of the four segments in the food market.

Price endogeneity can be a threat to identification, as in most demand estimations. In this case, beef prices were endogenously determined by the packers, who were monopolistic sellers on the market. Following Hausman, Leonard, and Zona (1994), I use the average price at the census region as an instrument for city-level prices to address the endogeneity concern in the lower-level estimation. Regional prices reflect local cost factors such as wages and transportation; they are correlated with city-level prices but are uncorrelated with unobserved demand shocks and can therefore be a valid instrument.[43] Table 7 reports the estimated compensated own-price and cross-price elasticity for the lower-level.[44] The own-price elasticity for beef estimated at the mean is –1.42, which is within the range of other own-price elasticities of beef from other studies.[45] Demand for other meat items appears to be more elastic, which may reflect a general

[42] *The National Provisioner*, April 6, 1918, page 44.

[43] The survey questionnaire asked for the annual average quantity and cost on food. The survey was conducted in different months, and respondents might base their answers on recent purchases, but only a small fraction of the price variation can be explained by time. I report the analysis of variance of prices in Appendix Table 4. As shown in columns (4) and (5), a significant fraction of the total price variance can be attributed to regional variation.

[44] See Appendix Table 5 for the elasticity estimation of the upper level.

[45] Price elasticity ranges from –0.998 in the U.S. in 1993 (Kinnucan, Xiao, and Hsia, 1996) to –1.19 in the 1970s (Eales

preference for beef as households spent half of their meat budget on beef.

Table 7: Lower-Level Price Elasticity

	(1) Beef	(2) Pork	(3) Poultry	(4) Other
Beef	-1.415***	0.940***	0.238***	0.237***
	(0.129)	(0.102)	(0.073)	(0.068)
Pork	3.083***	-4.741***	-0.055	1.713***
	(0.336)	(0.458)	(0.222)	(0.304)
Poultry	1.439***	-0.102	-1.691***	0.354**
	(0.444)	(0.411)	(0.392)	(0.172)
Other	0.485***	1.066***	0.119**	-1.670***
	(0.140)	(0.190)	(0.058)	(0.138)

Note: Standard errors are in parentheses. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

8.3 Model Fit

Because I do not impose an equilibrium assumption of the cartel behavior for the estimation, one concern is that the cartel may not behave optimally during the non-manipulation period, so the observed market outcome may not match the model. Though there is no evidence of deviation on the input market after the cartel suspended the weekly collusive meetings, as discussed in section 3.2, there may be operation frictions or deviation on the beef wholesale market that prevented the packers from jointly maximizing their profit.

I examine the model fits by comparing the actual cartel quantity reported in the data with the model prediction for the non-manipulation period. Appendix Figure 2 plots the predicted cartel quantity against the observed purchase. The predicted values largely replicate the distribution of the actual quantity observed in the data. In other words, the cartel's behavior after 1913 is consistent with the standard monopsony model. In a few cases, I observe more than 8,000 daily purchases and the model predicted a lower cartel quantity. These outliers all occurred at the Chicago stockyard during the winter months of 1916, suggesting that there were potential unobserved shocks in the market for this particular period that were not captured in the model.

9 Counterfactuals

In this section I use the estimated model to simulate counterfactual outcomes for the manipulation period, assuming the cattlemen and the cartel behaved the same way they did during the post-1913 period. I first quantify the effects on the wholesale cattle market by comparing the observed market outcome under cartel manipulation with the counterfactuals under a standard monopsony. In addition, from a policy perspective, antitrust regulators may also care about how disrupting cartel manipulation could influence downstream consumers. Therefore, I also

and Unnevehr, 1993), to –1.95 in post-WWII Australia (Murray, 1984).

calculate the counterfactual wholesale refrigerated beef prices and the corresponding changes in household expenditure. These two measures together allow me to evaluate the effect of cartel manipulation on both the aggregate market outcome and the distributional effect on individual sellers and buyers.

9.1 Solving for Counterfactual Equilibrium

Following the equilibrium definition in section 7.3, I find the counterfactual equilibrium price by solving (12). The cartel's optimal decisions are governed by the spot market supply of cattle and downstream demand for beef. On the demand side, I use the household price elasticity derived from the AIDS model to approximate the wholesale demand for beef. On the supply side, the inverse supply curve $q(p_t)$ requires two main components: the parameters γ_p and γ_x and the total cattle supply at the market Z_t. γ_p and γ_x are estimated from the non-manipulation period in section 8.1. I use the observed cattle shipment during the manipulation period for Z_t and solve for the optimal cartel price, as described in (12), by numerically finding the value that maximizes the profit function.[46] I then calculate the corresponding counterfactual cartel quantity using the inverse supply defined in (10).

This counterfactual is of partial equilibrium in nature since the model focuses primarily on the spot market and does not account for adjustment in aggregate cattle production or shipment. In particular, this calculation corresponds to a lower bound for the effect of the cartel manipulation strategy: absent price signal manipulation, the wholesale cattle price would be higher, which in turn would increase aggregate supply at the stockyard. The observed shipment I used for Z_t would be lower than the "true" counterfactual that allows for adjustment in cattle production. The results are thus lower bounds of the cartel effect.

This approach also implicitly allows for other frictions or inefficiencies that are hard to model or estimate. For example, litigation and public opinion pressure may discourage the cartel from capturing the full monopoly profit during the manipulation period. Past research also suggests that, even for legal cartels with no litigation threats, many cartels capture only part of the theoretical monopoly profits due to organizational frictions (Röller and Steen, 2006; Asker, Collard-Wexler, and De Loecker, 2019). Therefore, instead of imposing strong equilibrium assumptions on the cartel, I compare the observed market outcomes under the complicated manipulation strategy with a simple and well-understood theoretical benchmark. The difference can be interpreted as the "empirical damage" to the market after incorporating all potential cartel inefficiencies.

9.2 The Livestock Market Suffered Larger Losses under Manipulation

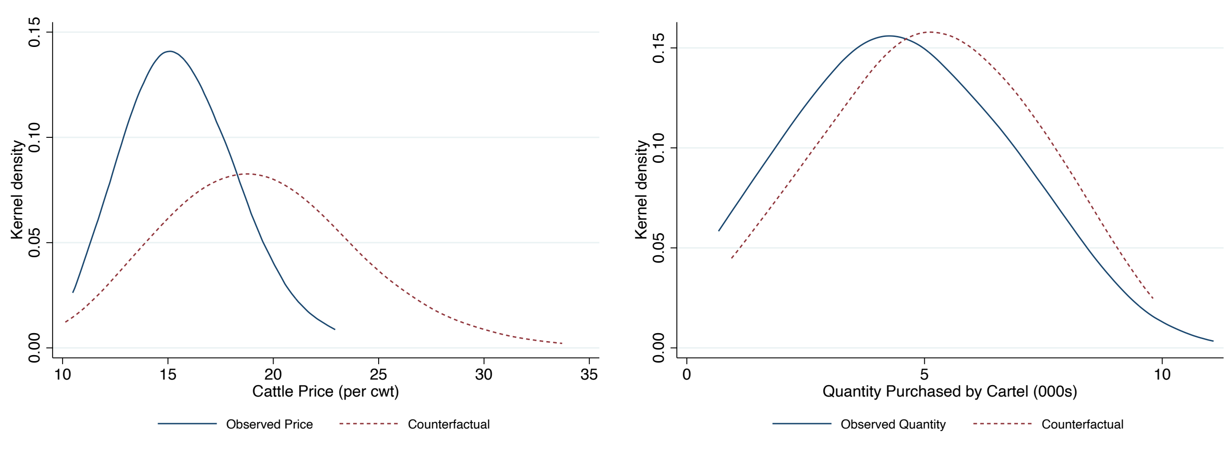
The cartel's manipulation strategy reduced the spot market price and the total quantity traded at the stockyards. Figure 9 presents the distributions of observed and counterfactual wholesale cattle prices and quantities. Compared with the observed market price, the average cattle wholesale

[46]The average price for cattle was between \$10 and \$25 (see Figure 8). I use the interval (0,50) for the solution to search for the optimal price.

price would be 23.4% higher in the counterfactual scenario, or $43.9 per head.[47] In comparison, cattlemen's average profit in 1909 was $28.[48] Interrupting the cartel manipulation would increase the profit margin by 57% for cattlemen.

Meanwhile, the average daily slaughter would increase by 14%, from 4,475 heads in the data to 5,097 heads per day in the counterfactual scenario. This adds up to about 15,000 more heads of cattle per week sold at the four stockyards. Assuming the urban beef supply adjusted by the same percentage and given that the average household consumed 168 pounds of beef per year (see Table 3), this increase also implies that the average household consumed 23.3 pounds more of beef per year absent of the cartel manipulation.

Figure 9: Counterfactual and Observed Cartel Prices and Quantities



(a) Cartel Price

(b) Cartel Quantity

9.3 Heterogeneity across Markets

The manipulation strategy has heterogeneous effects across markets. The difference is driven by the non-price elements of the supply curve, which are captured by the elements in $\mathbf{X_{jt}}$, which includes local weather conditions and stockyard-by-week-of-year fixed effects. Differences in seasonality and weather patterns naturally influenced cattlemen's sales decisions. In addition, stockyards have different unobserved features, such as proximity to input material markets or ease of outbound transportation to the alternative market, which are all captured in the fixed effects.

Table 8 tabulates the observed and counterfactual average wholesale prices and quantities by stockyard. Larger stockyards, such the Chicago Union Stock Yards were less influenced by the manipulation strategy. For example, on average, the observed price in Chicago is 93% of the counterfactuals, while the ratio is below 80% for the other three stockyards. Meanwhile, Chicago

[47]The average price is $3.66 lower. For a 1,200-lb cattle, this implies a $43.9 increase.
[48]See Skinner (1909). All dollar values are adjusted to 1920 dollars.

also has the smallest quantity changes under the counterfactual scenario.[49] Part of this could be due to the city being a major transit hub with easier transportation to outside markets and having a large number of feedlot farmers nearby (see Figure 1) who were less affected by the high shipping cost. These factors all limited the cartel's market power over sellers and thus created less distortion.

Table 8: Empirical and Counterfactual Market Outcomes by Stockyard

	(1) Chicago	(2) Kansas City	(3) Omaha	(4) St. Louis	(5) Total
Cartel Quantity (000s)					
Observed	5.85	4.55	2.28	1.80	4.48
	(1.39)	(1.47)	(0.62)	(0.66)	(1.92)
Counterfactual	6.57	5.08	2.87	2.14	5.10
	(1.01)	(1.28)	(0.79)	(0.70)	(1.84)
Spot Market Price (per cwt)					
Observed	16.18	15.35	15.09	17.02	15.66
	(2.44)	(2.46)	(2.12)	(1.71)	(2.41)
Counterfactual	17.06	19.08	23.26	21.28	19.32
	(2.61)	(2.29)	(3.98)	(3.99)	(3.82)

Note: The table presents the average values by city. Standard deviations are in parentheses.

9.4 Manipulation Increased Beef Prices and Household Food Expenditure

Next, I compare the effect of cartel manipulation in the cattle market on downstream wholesale refrigerated beef prices. Under the standard monopsony strategy, the cartel purchased more cattle at the input market, leading to lower refrigerated beef prices in the downstream market. I first compare the counterfactual wholesale beef prices with the observed weekly prices in New York City, collected from the Bureau of Labor Statistics *Wholesale Prices* series. Figure 10(a) shows the distribution of counterfactual and observed beef prices. If the cartel switched from the manipulation to the standard monopsony strategy, the average downstream beef price would reduce by 6%, from 20.5 cents to 19.2 cents per pound. For an average household that consumed 168 pounds of beef per year, this price reduction would save the family $2.1. However, this back-of-the-envelope calculation understates the influence on consumers since lower beef prices would induce households to consume more beef while also substituting away from other food items.

Next, I calculate the total food expenditures a household needs to achieve the same utility level as under the cartel manipulation. Specifically, let p_o and u_o denote the observed price vector and utility under the manipulation strategy, p_s the counterfactual prices under the standard monopsony model, and $E(u, p)$ the total food expenditure. $E(u_o, p_o)$ represents the total food expenditure with observed beef prices, and $E(u_o, p_s)$ represents the expenditure with counterfactual beef prices.[50] I assume perfect competition in other agricultural product markets so that

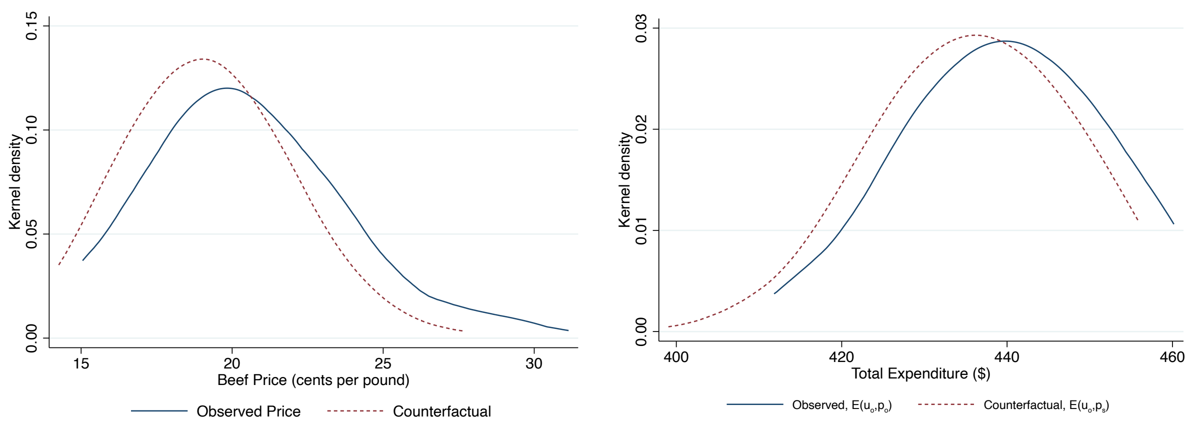
[49] Appendix Figure 3 and Appendix Figure 4 plot the complete distribution of counterfactual prices and quantities by stockyard.

[50] The difference between the two expenditures is the compensating variation (CV), defined as $CV = E(u_o, p_s) -$

their prices do not respond to changes in the cartel strategy. For the calculation, I use the reported New York City beef price in p_o and the simulated prices in p_s while holding the prices of other food items to be the same as reported in the cost of living survey.

Figure 10(b) shows that, in the non-manipulation counterfactual, the average household annual food expenditure would reduce by $3.6, which is equivalent to 13.4% of the average weekly wage. Compared to the effects on cattle sellers, the cartel had a much smaller impact on downstream consumers. The difference is largely driven by the inelastic cattle supply and much more elastic demand for beef. Though the cartel dominated the refrigerated beef wholesale market, urban consumers can easily substitute beef with other food items and thus limiting the cartel's ability to charge higher prices. The large damage on the upstream cattle market and the relatively small effect on downstream urban consumers also reflect the fact that the cattlemen actively pushed to regulate meatpackers' market power. In contrast, consumers were largely absent in this policy discussion.[51]

Figure 10: Counterfactual and Observed Beef Prices and Total Food Expenditure



(a) Refrigerated Beef Prices

(b) Total Food Expenditure

10 Conclusion

In this paper, I estimate the effect of signal manipulation by a monopsony cartel on the market by analyzing the U.S. meatpacking cartel. The analyses leverage changes in the legal environment that forced the cartel to change from a manipulation strategy to a standard monopsony strategy. I find that the manipulation strategy created a larger welfare loss than what a standard monopsony model would suggest. Under its manipulation strategy, the meatpacking cartel purchased fewer cattle at lower prices than it would have under a standard monopsony strategy

$E(u_o, p_o)$. Appendix Figure 5 shows the distribution of observed and counterfactual expenditures used to construct the compensating variation.

[51] For example, in 1916, ten people in the business were invited to give statements at the U.S. House Judiciary Committee hearing on the investigation of the beef industry. Except for one trade journal editor, all the other nine witnesses were cattle ranchers or feedlot farmers (House Committee on the Judiciary, 1916).

while increasing downstream wholesale beef prices and total household expenditure on food. Without adopting new legislation or breaking up the cartel through forced divestiture, changes in legal interpretation and antitrust enforcement forced the cartel to abandon the manipulation and benefited both upstream cattlemen and downstream consumers.

The historical case has important implications for contemporary markets. Absent contracts or futures markets, which is often the case in developing countries, small sellers usually rely on spot markets for sales.[52] Without adequate supervision over large buyers, the market can suffer significant distortions. My results also highlight the difficulties in regulating monopsony power. Though the cartel also harmed consumers, their losses were much smaller than those of the cattlemen. In other words, policies focusing primarily on consumer welfare may limit regulators' ability to address the adverse effects of monopsony power on small producers.

[52]The recent work by Garrido, Kim, Miller, and Weinberg (2021) shows that sellers are not necessarily better off when they switched to contracts. Because the contract prices were usually linked to the spot-market price, such arrangements distort packers' bidding strategy and end up depress the price paid for cattle sold through either contracts or spot markets.

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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] *United States v. Swift & Co.* 122 F 529

[b] *Swift & Co. v. United States*, 196 U.S. 375

B Proof of Proposition 1

Suppose $\theta' > \bar{\theta}$. Because $p_c^{-1}()$ is increasing, and $v(.)$ is decreasing, for $\theta' > \bar{\theta}$, we have

$$\begin{aligned} p_c^{-1}(v(\theta')) &< p_c^{-1}(v(\bar{\theta})) \\ v(\theta') &< v(\bar{\theta}) \end{aligned} \tag{13}$$

which implies that,

$$\int_{\omega \geq p_c^{-1}(v(\bar{\theta}))} \beta(\omega|s) p_c d\omega > \int_{\omega \geq p_c^{-1}(v(\theta'))} \beta(\omega|s) p_c d\omega \tag{14}$$

$$v(\bar{\theta}) \int_{\omega < p_c^{-1}(v(\bar{\theta}))} \beta(\omega|s) d\omega > v(\theta') \int_{\omega < p_c^{-1}(v(\theta'))} \beta(\omega|s) d\omega \tag{15}$$

Inequality (14) means that seller θ' would have lower expected payoff if he ships to the market and sells to the cartel. Intuitively, seller θ' has lower outside value once he arrives at the stockyard, as described in (13). He would accept the cartel prices at lower state, which leads to a lower expected payoff if he sells to the cartel. At the same time, because he also has lower outside value, and would leave the market at lower state, the expected payoff from leaving the market is also lower, as in (15).

Meanwhile, the shipping cost from farm to the stockyard increases in θ, so

$$m(\theta') > m(\bar{\theta}) \tag{16}$$

Combine (14), (15), and (16), we have

$$\mathbb{E}[U_{ship}(\bar{\theta}, s)] > \mathbb{E}[U_{ship}(\theta', s)] \tag{17}$$

C 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	Source
Chicago	Chicago Union Stockyard Annual Report Chicago Board of Trade Report *Drover's Journal* *The National Provisioner*
Kansas City	*The National Provisioner*
Omaha	*The National Provisioner* *Nebraska Bee*
St. Louis	Annual Statement of the Trade and Commerce of St Louis.

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 standard for "Choice" steer of 1,100 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.

1917-1919 Cost of Living Survey The following table summarizes the food items included in each category for the demand estimation:

Variables Used in Aggregate Categories

Variable	Items
Meat Products	
Beef	Beef Steak, Beef Roast, Beef Stew
Pork	Pork
Poultry	Poultry Hens
Other	Fish, Seafood, Cured Meat
Food Segments	
Meat	Beef, Pork, Poultry, Other
Dairy	Whole Milk, Skimmed Milk, Condensed and Evaporated Milk, Buttermilk, Cream, Ice cream, American Cheese, Butter
Starch	Wheat Flour, Corn Meal, Grits, Corn Starch, Wheat Bread, Rolls and Buns, Crackers, Cake and Cookies, Pies, Pasta, Rice, Tapioca
Vegetable	Cabbage, Spinach, Peas, String Beans, Tomato, Onion, Corn, Lettuce, Celery, Navy Beans, Irish Potato, Sweet Potato, Canned Beans, Canned Peas, Canned Corn, Canned Tomatoes

D Demand Estimation

The lower-level demand of different meat products can be simplified by expressing the Marshallian demand as expenditure shares:

$$\omega_i = \alpha_i + \Sigma_j \gamma_{ij} \ln p_j + \beta_i \ln(\frac{X_s}{P_s}) + \varepsilon_i \tag{18}$$

where P_s is the Stone price index defined as

$$\ln P_s = \Sigma_i \omega_i \ln p_i \tag{19}$$

ω_i is the expenditure share of product i in the meat segment. X_s is the total expenditure on the meat segment, and the error term ε_i accounts for both measurement error and potential demand shocks.

Following the literature, I also impose the three sets of restrictions on the coefficients:

Adding-up: the expenditure shares always sum up to 1, implying

$$\Sigma\alpha_i = 1; \Sigma\beta_i = 0; \Sigma_i \gamma_{ij} = 0 \ \forall j \tag{20}$$

Homogeneity: Marshallian demand is homogeneous of degree zero in prices.

$$\Sigma\gamma_{ij} = 0 \ \forall i \tag{21}$$

Symmetry: follows from Shepard's Lemma,

$$\gamma_{ij} = \gamma_{ji} \ \forall i, j \tag{22}$$

At the higher-level, allocation of expenditure among broad food segments (meat, dairy, starch, etc.) follow the same structure:

$$\omega_S = \alpha_S + \Sigma_H \gamma_{SH} \ln p_S + \beta_S \ln(\frac{X}{P}) + \varepsilon_S \tag{23}$$

where all variables denoted by S refer segment rather than product level values. X is the total food spending, and P is the Stone price index at the segment level. The analogous restrictions of (20) to (22) also apply to the higher-level.

The estimated demand parameters allow me to calculate the unconditional elasticities for counterfactual analysis (Anderson and Blundell 1983). The own- and cross-price elasticities at the lower level are:

$$\epsilon_{ij} = -\delta_{ij} + \frac{1}{\omega_i}(\gamma_{ij} + \beta_i(\alpha_i + \Sigma_k \gamma_{kj} \ln p_k)) + \omega_j(1 + \frac{\beta_i}{\omega_i}) \tag{24}$$

where $\delta_{ij} = 1$ if $i = j$ and $\delta_{ij} = 0$ otherwise. The higher level has the analogous expression with parameters estimated from the segment level expenditure decisions.

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: Robustness: Prices vs. Shipments

Dependant Variable: Price	First and Second Half of Manipulation Period		Sample with $\geq$ 3 Stockyards	
	(1)	(2)	(3)	(4)
	1903-1908	1909-1912	Manipulation	No Manipulation
Daily Average Shipment (000s)	0.017	-0.013	0.041	0.097*
	(0.021)	(0.018)	(0.029)	(0.031)
Time Controls	Yes	Yes	Yes	Yes
Weather Controls	Yes	Yes	Yes	Yes
Cost Controls	Yes	Yes	Yes	Yes
Observations	598	713	1319	780
Adjusted R-Squared	0.68	0.71	0.78	0.63

Note: The table shows the regression coefficients α_z of price on average daily shipment, $p_{kt} = \alpha_z Z_{kt} + X_{kt} + \eta_{kw} + \tau_y + \epsilon_{kt}$. Weather controls include quarterly lagged weighted average temperature and rainfall as well as the current temperature and rainfall in the counties where the stockyards were located. The cost controls include quarterly lagged corn and hay prices. Columns (1) and (2) cover the first and second halves of the manipulation period. The point estimates for the manipulation period are both statistically zero. Columns (3) and (4) use only the sample with at least three operating stockyards to avoid influence of multiple simultaneous market closure on shipment decisions. Results are consistent with the estimation in Table 3. Standard errors are clustered by stockyard. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix Table 3: Summary Statistics of Household Expenditure Survey

	Mean	SD
Annual Household Expenditure		
Main Food Groups (meat,dairy, starch, vegetables)	319.36	100.49
All food (includes coffee, candy, etc)	544.37	149.66
Total expenditure by the household	1419.45	394.84
Income		
Weekly Wage Rate of Husband	26.61	8.25
Household Total Earnings	1434.04	411.38
Annual Total Consumption (lbs.)		
Beef	168.11	108.38
Pork	41.37	54.73
Poultry	23.37	34.31

Note: Summary statistics are calculated from the *1917–1919 Consumer Expenditure Survey* (Bureau of Labor Statistics, 1992). The sample excludes cases where the household did not report total cost, or the implied prices were the top 0.1 percentile. This left with 12,802 households in the sample.

Appendix Table 4: Analysis of Price Variance

Product group/segment	(1) SS Region	(2) SS Month	(3) Total SS	(4) Percentage Explained by Region (%)	(5) Percentage Explained by Time (%)
Meat Products					
Beef	11.81	0.28	14.47	81.58	1.90
Pork	4.93	2.78	7.02	70.17	39.53
Poultry	5.89	0.41	8.29	71.03	4.96
Other	7.08	4.85	23.55	30.06	20.59
Food Segments					
Meat	4.35	0.54	5.28	82.27	10.19
Dairy	4.00	0.56	4.76	84.06	11.85
Starch	0.23	0.13	0.76	29.82	17.38
Vegetable	0.30	0.11	0.45	68.29	24.41

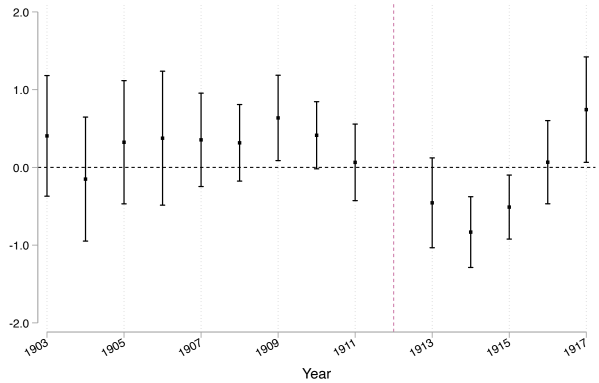
Note: Prices are aggregated up to city level.

Appendix Table 5: Higher-Level Price Elasticity

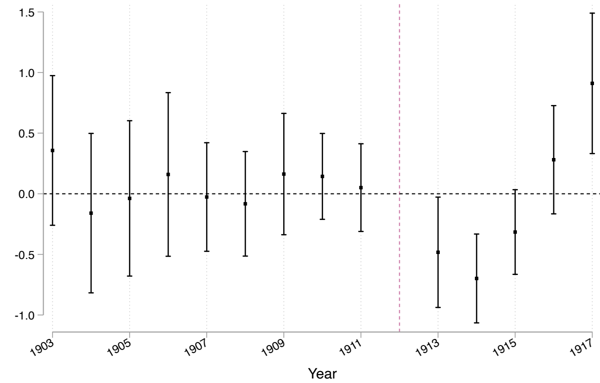
	Price			
	(1) Meat	(2) Dairy	(3) Starch	(4) Vegetable
Meat	-0.643***	0.376***	0.042	0.225**
	(0.142)	(0.103)	(0.077)	(0.095)
Dairy	0.385***	-0.888***	0.381***	0.122
	(0.106)	(0.144)	(0.090)	(0.099)
Starch	0.048	0.426***	-0.510***	0.035
	(0.089)	(0.101)	(0.107)	(0.054)
Vegetable	0.406**	0.214	0.055	-0.675***
	(0.171)	(0.175)	(0.086)	(0.184)

Note: Standard errors in parentheses. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

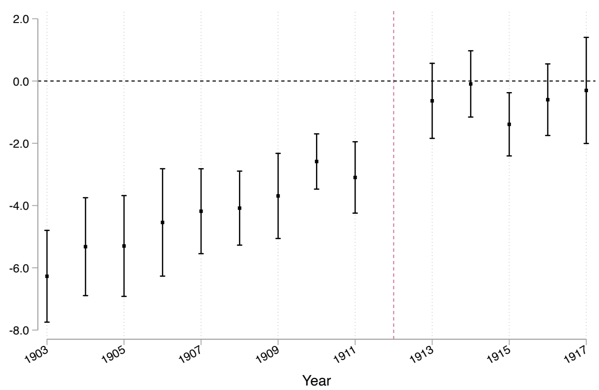
Appendix Figure 1: Changes in Market Outcome



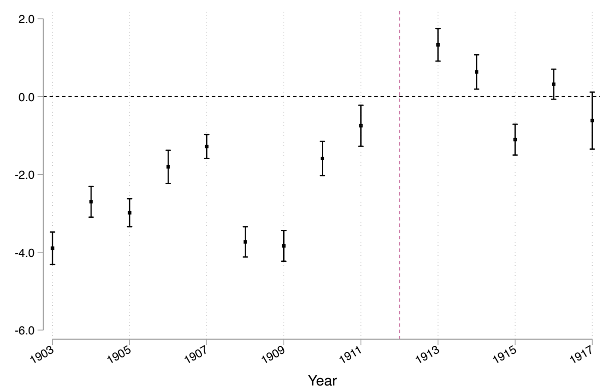
(a) Total Shipment



(b) Quantity Purchased by Cartel



(c) Cartel Price



(d) Sellers' Margin

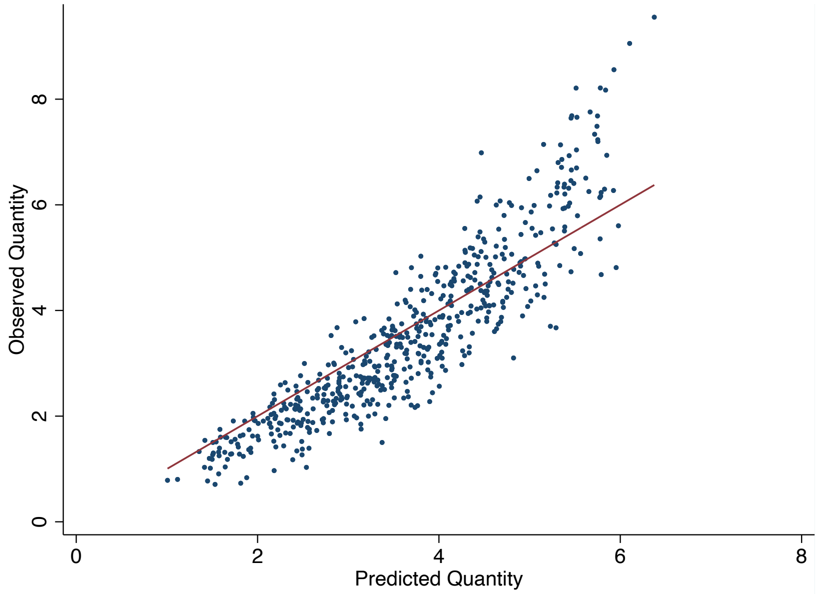
Note: The figures above plots the estimated coefficients β_t Coefficients are normalized relative to 1912. Standard errors are clustered by year. The sample excludes data between December 1911 and July 1912, when the cartel was on trial for the collusion.

Appendix Figure 1 above plots the even-study equation:

$$y_{kt} = \sum_{t=1903}^{1917} \beta_t \mathbb{1}(Year = t) + X_{kt} + \eta_{kw} + \epsilon_{kt} \tag{25}$$

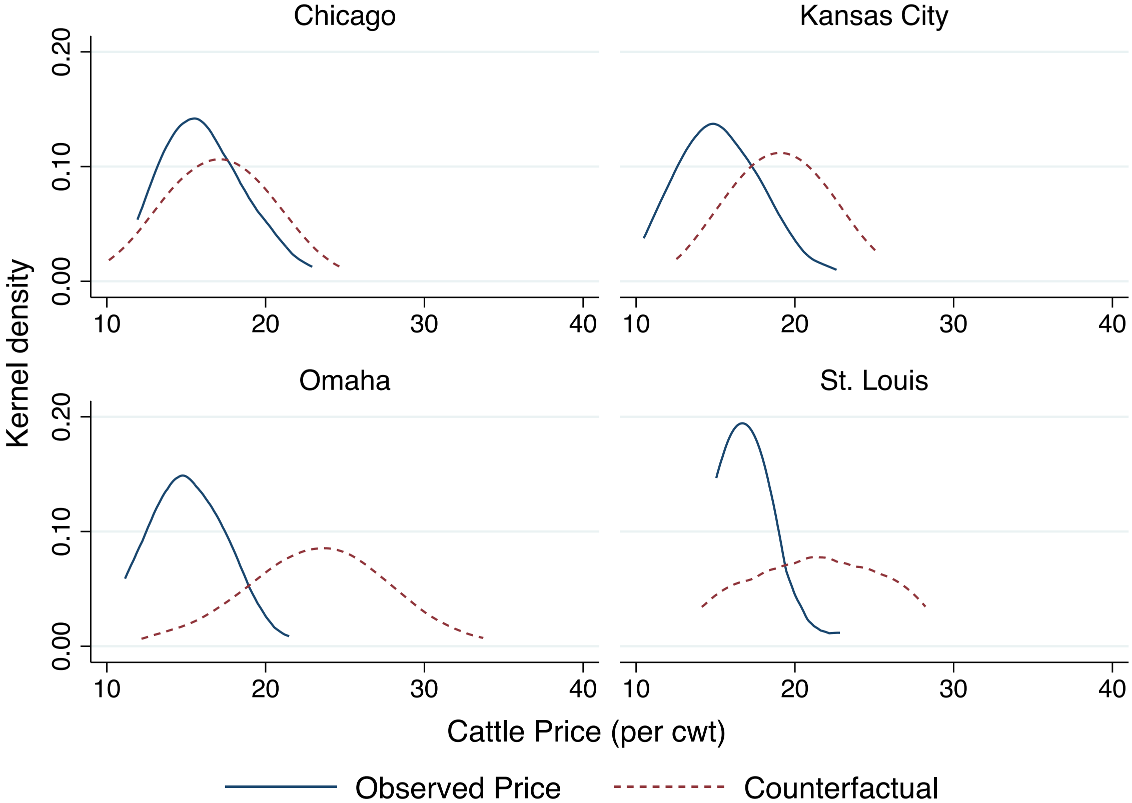
where y_{kt} is the outcome variable for stockyard k at time t; η_{kw} is the stockyard-by-week-of-year fixed effect, which captures the seasonality of the cattle market at each stockyard; X_{kt} includes weather and cost controls. The weather controls include lagged average temperature and rainfall, as well as the current temperature and rainfall in the counties where the stockyards were located. The cost controls include 4-month lagged corn and hay prices.

Appendix Figure 2: Observed vs Predicted Cartel Quantity



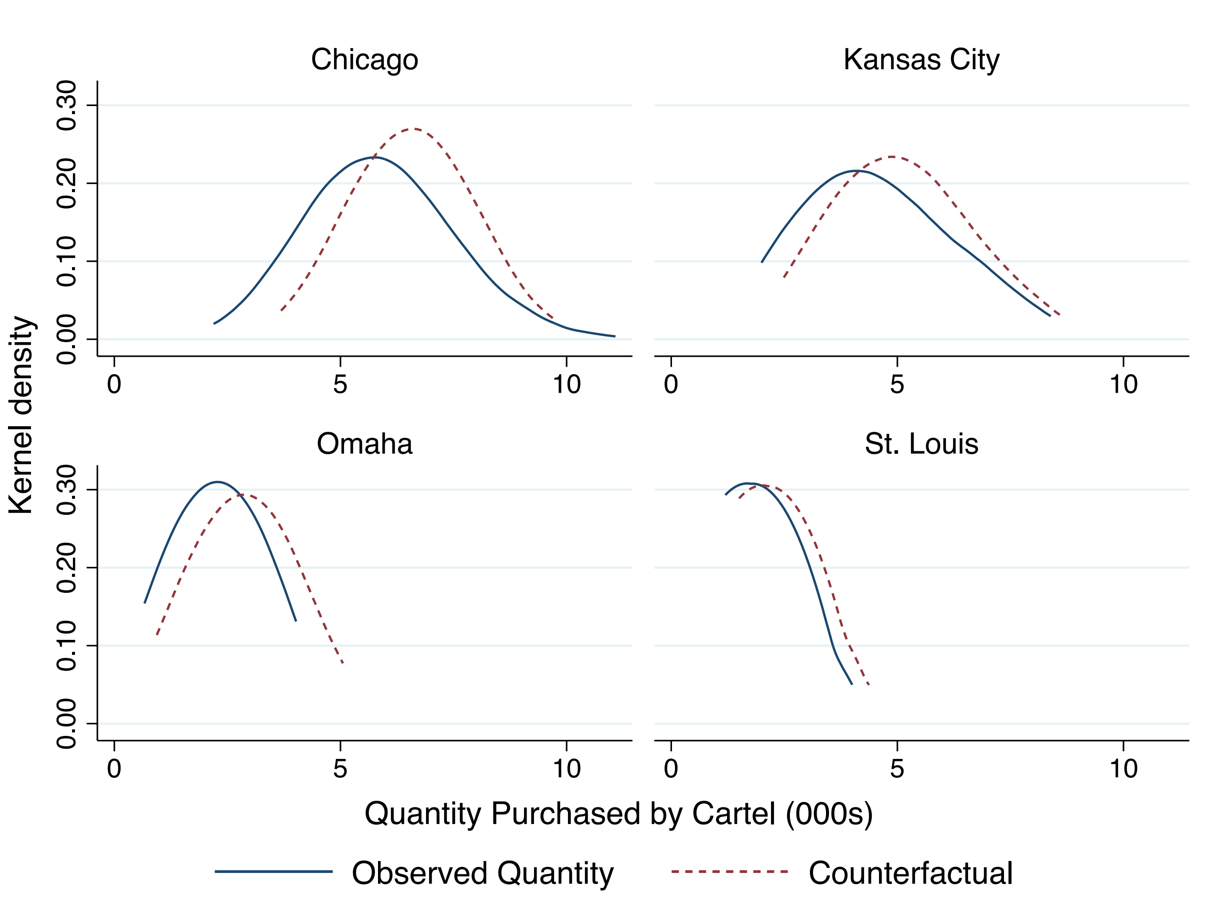
Note: The graph plots the observed versus predicted cartel purchase of cattle at the stockyard. The red line is the 45-degree diagonal line.

Appendix Figure 3: Distribution of Counterfactual and Observed Cartel Price by Stockyards



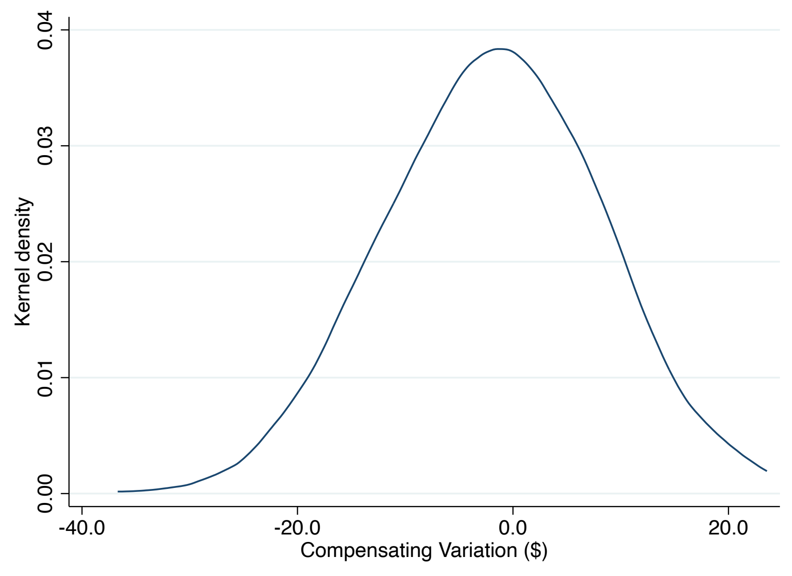
Note: The value of the counterfactual prices is calculated by solving (12).

Appendix Figure 4: Distribution of Counterfactual and Observed Cartel Quantities by Stockyards



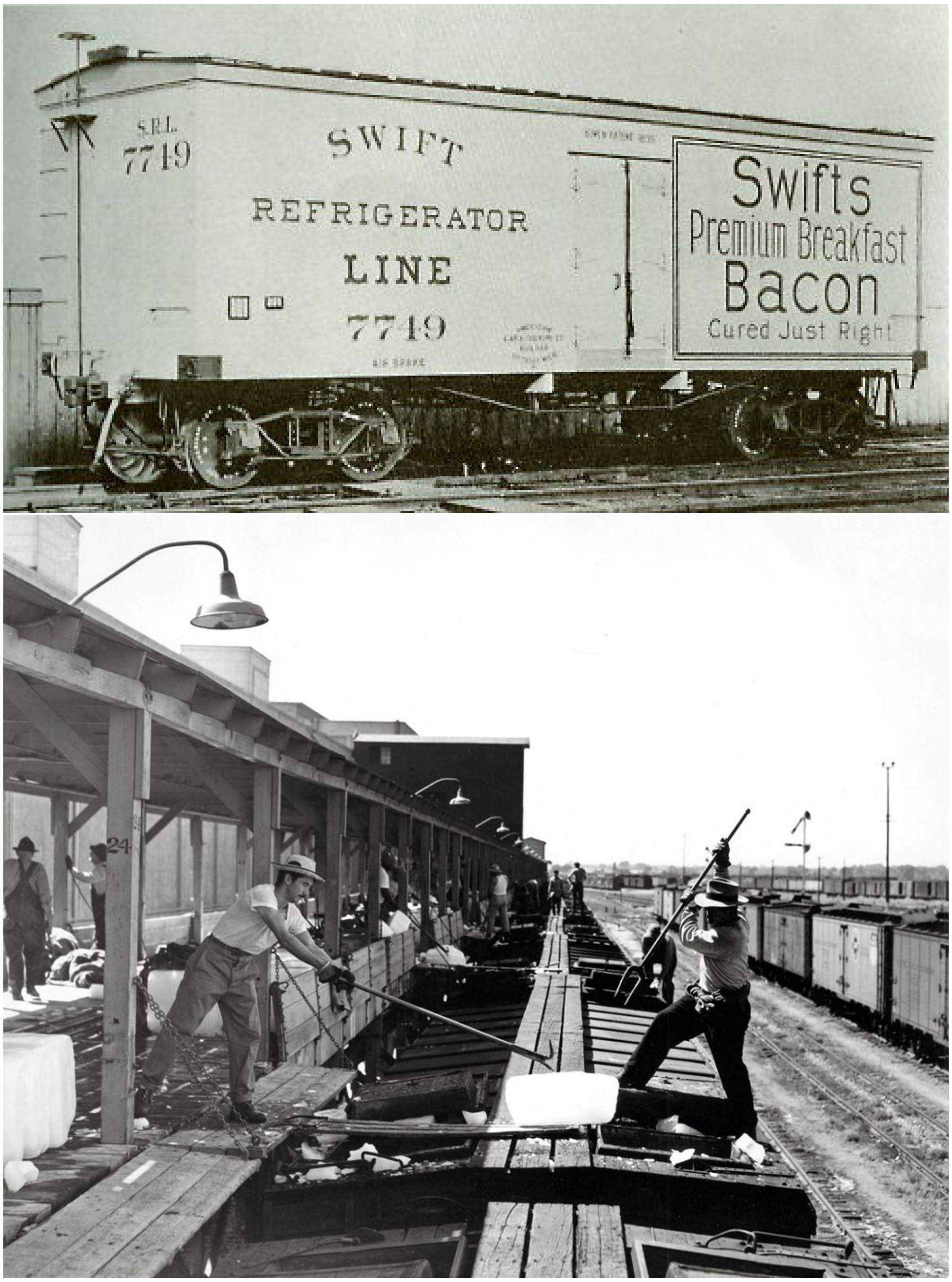
Note: The value of the counterfactual quantity is calculated by solving (12).

Appendix Figure 5: Compensating Variation



Note: The graph plots compensating variation, defined as the difference of total expenditures under different prices that allow households to achieve the same level of utility as under the cartel manipulation, or $CV = E(u_o, p_s) - E(u_o, p_o)$. See Figure 10(a) for the distribution of $E(u_o, p_s)$ and $E(u_o, p_o)$.

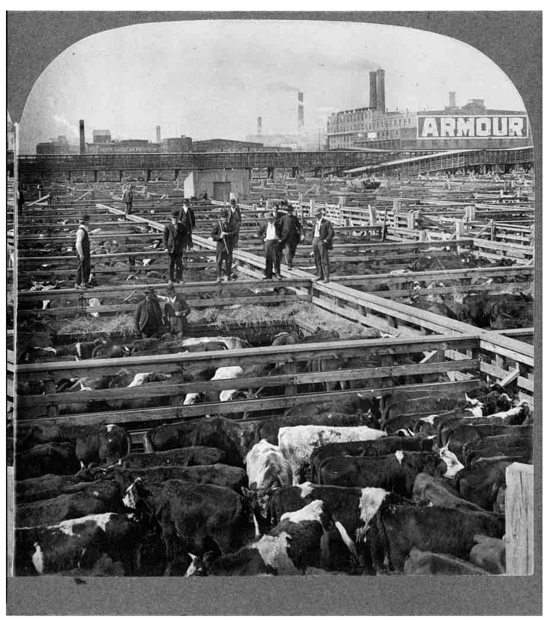
Appendix Figure 6: Swift Ice-Refrigerated Rail Car and Ice-Manufacturing Plant



Appendix Figure 7: Cattle Slaughter Relied Primarily on Manual Labor

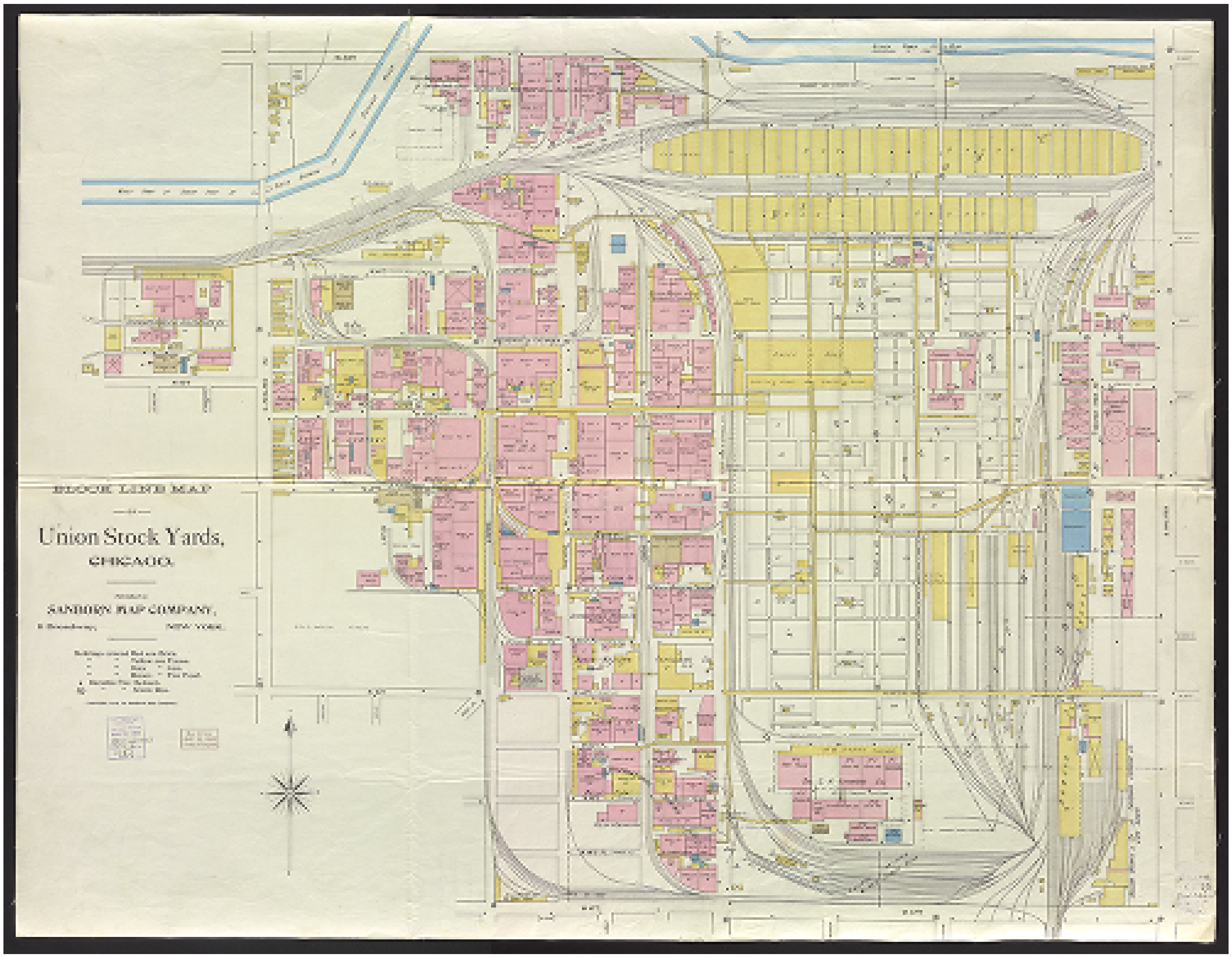
Note: H.C. White Co. Chicago - Meat Packing Industry: dressing beef–removing hides and splitting backbones, Swift's Packing House, Chicago, U.S.A. Chicago Illinois, 1906. North Bennington, Vt.: H.C. White Co., Publishers. Photograph. https://www.loc.gov/item/2006679958/.

Appendix Figure 8: 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 9: 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.