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

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Abstract

This paper quantifies the effects of a monopsonistic cartel on the market when the cartel employs a dynamic strategy to manipulate small sellers. When production or shipment decisions precede spot-market sales, monopsonists can manipulate current prices to alter future supply, potentially achieving higher collusive profits. This suggests that standard static models may underestimate the effect of monopsonistic cartels. This paper examines the historical case of the U.S. meatpacking cartel, which manipulated market prices to attract large cattle shipments, then exploited the inelastic spot-market supply to obtain the input materials at lower prices. The analyses leverage exogenous regulatory changes that forced the cartel to switch from a dynamic to a static strategy. I develop and estimate a structural model of the wholesale cattle market under the static strategy. I then quantify the effect of dynamic cartel manipulation by comparing the empirical market outcomes under manipulation with counterfactuals suggested by the static model. I find that dynamic manipulation harmed cattle sellers by enabling the cartel to buy fewer cattle at low prices than it would have under a static model. The manipulation strategy also harmed downstream consumers by increasing beef prices and thus total household food expenditures.

Key Words: monopsony, cartel, market manipulation, agriculture

JEL Classifications: D2, L1, L4, N6, L66

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1 Introduction

Policymakers and academics are increasingly concerned about the anticompetitive effects of monopsony power in a wide range of industries. However, despite recent policy efforts to address monopsonies’ adverse effects, economic theory provides limited understanding of monopsonistic cartel strategies. Standard monopsony models focus primarily on static and immediate responses from the market. However, sellers in markets with substantial time-to-ship or time-to-build can be vulnerable to a more complex form of dynamic manipulation: because sellers need to make future production or shipment decisions based on current market information, they have to commit to the market before observing the realized spot-market price at the time of delivery. If a monopsonistic cartel incorporates the delayed supply responses in the collusive strategy, the canonical static model may fail to properly assess the cartel damage on the market.

This paper estimates the impact of a dynamic cartel strategy on the market 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; they also 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 dynamic monopsonistic cartel 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.” Second, exogenous changes in the regulatory environment forced the cartel to switch from the aforementioned dynamic strategy to a static fixed-market-share agreement in 1913, while other features of the market remained unchanged. Thus, I observe the market outcomes under both dynamic and static strategies but with the same market participants. This allows me to compare the empirical outcomes under the dynamic strategy to counterfactuals suggested by the well-understood static monopsony model.

I compiled high frequency data from numerous primary sources for the empirical analysis.

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2 The Department of Justice and the Federal Trade Commission issued guidelines in 2016 regarding no-poach and non-compete agreements. See also Senate Committee on the Judiciary (2004); Department of Justice (2012); Council of Economic Advisors (2016).

3 Jeon (2017), for example, describes the time-to-build feature in the container shipping industry.

4 See for details on the evolution of the meatpacking cartel.

The main variables of interest are cattle shipment to the stockyards, spot-market prices, and cartel quantities. The weekly data is compiled from the livestock trade journal, *The National Provisioner*, between 1903 and 1917 for the four largest stockyards, which collectively produced more than 58% of U.S. refrigerated beef. To control for input cost, I collected monthly corn and hay prices from *Chicago Board of Trade Annual Report*. I also collected wholesale prices of live hogs in New York City to construct instrument for demand shocks.

I start by providing descriptive evidence on how dynamic manipulation affects the cattle wholesale market. I first show that such manipulation led to different aggregate market outcomes: under manipulation, on average, 17% more cattle were shipped to the stockyards for sale, while the cartel price is 4% lower. The lower realized price implied that cattlemen's margin, defined as the net between the cattle price and input costs, was 24% lower. I also show that, consistent with narrative evidence, the cartel was successful at manipulating cattlemen's shipment decisions. Under cartel manipulation, higher shipment quantities did not correspond to higher realized prices. In other words, cattlemen were “tricked” to believe that the market would be good when they made large shipments; once the cattle arrived at the stockyards, however, cattlemen ended up facing lower-than-expected spot-market prices. Without manipulation, however, more cattle were shipped when the market price was higher. This result suggests that cattlemen could correctly predict market conditions once the cartel stopped their dynamic manipulation.

The reduced-form results provide only limited information about the dynamic strategy. To measure the level of distortion created by the dynamic cartel strategy on both market price and quantity, I need to construct the counterfactual market outcomes absent of dynamic cartel manipulation. This requires a model of static monopsony.

The main empirical strategy measures the effects of the dynamic cartel strategy by comparing the counterfactuals predicted by the static strategy with the observed market outcomes under the dynamic strategy. Under the static strategy, the cartel chooses the price at the input market to maximize per period profit, given the cattle supply and beef demand. On the supply side, I use a discrete choice model with differentiated buyers (Berry, 1994): cattlemen either choose to sell to the cartel at the spot-market price or to try the competitive outside market. To address the price endogeneity issue, I use prices of a substitute for beef in the urban market, live hogs, as instrumental variables to trace out the spot-market cattle supply curve. On the demand side, I use the Almost Ideal Demand System (Deaton and Muellbauer, 1980) with two-stage budgeting to estimate urban households’ demand for beef.

I estimate the cattle supply and beef demand using data after 1913, when the cartel was forced to adopt the static strategy. I then solve for the counterfactual cattle prices and quantities, as well as wholesale beef prices, for the dynamic period before 1913. The difference between the observed market outcomes under the dynamic strategy and the counterfactuals suggested by the static model is, therefore, the “additional” damage of the dynamic cartel strategy not captured by standard models.

I find two sets of key results. First, on the cattle wholesale market, the dynamic strategy creates
larger damage to small sellers than what is suggested by the standard model: without the cartel manipulation, 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, on the downstream beef wholesale market, the dynamic strategy hurts urban consumers by reducing the beef supply and increasing the 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.

The empirical strategy exploits the unique data structure by taking the market outcomes under the dynamic cartel strategy as given. Though recent works provide insights to why individuals can make systematic mistakes, the empirical analysis usually requires specific assumptions on preferences or beliefs. In contrast, this paper remains agnostic about agents’ beliefs in the dynamic environment, and instead focuses on estimating the aggregate impact of the dynamic strategy on market outcomes. In spirit, this approach is similar to a growing body of research that estimates market distortions in complicated economic or institutional environments. Instead of specifying intricate models to fit particular market settings, many empirical works focus on comparing the observed outcomes to some benchmark counterfactuals derived from classic theories.

My research contributes to three strands of existing literature. First, it quantifies the effect of the monopsonistic cartel with dynamic seller responses on the input market. A growing literature on monopsony power (Chatterjee, 2019; Rubens, 2021) in the agricultural markets documents the negative effect of dominant buyers on prices. Similar works in labor markets (Ashenfelter, Farber, and Ransom, 2010; Azar, Berry, and Marinescu, 2019; Card, Cardoso, Heining, and Kline, 2018; Goolsbee and Syverson, 2019; Manning, 2003) also find that monopsonistic employers exert a negative effect on wages. 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 under dynamic market responses. My results suggest that the static model understates the welfare loss from monopsonistic market power.

Second, this paper contributes to the literature on the inner workings of cartels. Past research dissects specific cartel strategies across different market and regulatory environments (Marshall and Marx, 2012; Röller and Steen, 2006). Some have emphasized the role of communication in sustaining collusion (Genesove and Mullin, 2001; Harrington and Skrzypacz, 2011). I present new evidence that a monopsony cartel can use frequent communication to employ a more complicated dynamic strategy to manipulate the market. This paper provides a first-order estimate on the cartel damage and expands our understanding of the strategic toolkit available for cartels. The results also highlight the need for theoretical advances in monopsony collusion and coordinated

market manipulation.

Finally, the analysis complements previous research on the meatpacking cartel by quantifying the effect of the manipulation strategy. 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 impact of regulatory changes (Adudell and Cain, 1981; Libecap, 1992), the evolution of the cartel (Yeager, 1981), and innovation in management (Chandler Jr., 1993). I extend the past narrative and reduced-form results by highlighting the excess welfare loss created by the dynamic manipulation strategy.

The rest of the paper is structured as follows. Section 2 describes the meatpacking industry and the cattle wholesale market. Section 3 introduces the data. Section 4 presents descriptive evidence on the effectiveness of the dynamic strategy. Section 5 sets the analytical framework for the market under static strategy. Section 6 discusses identification of the spot-market supply and demand, and presents the estimation results. Section 7 presents the counterfactual analysis.

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 evolution of the regulatory environment between 1893 and 1918. The nature of the livestock market and the meatpacking industry provides the basis for the structural model I describe in Section 5. An exogenous regulatory change allows me to identify key parameters for the model I describe in Section 6.

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 now ship just the carcasses in tightly-packed refrigerated rail cars. On the one hand, refrigerated rail cars greatly 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. By the early 20th century, five firms (the “Big Five”) had come to dominate the meatpacking industry.

Figure 1 illustrates the production chain of the meatpacking industry. On 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 (Federal Trade Commission, 1919). The 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

8 Appendix Figure 5 shows the specialized rail cars and ice-manufacturing facilities along the rail lines.
market, the “Big Five” accounted for almost all cattle slaughtered at the stockyards (see Appendix Table 1). 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).

Figure 1: Meatpacking Industry Value Chain

2.2 Cattle Production and the Stockyard Spot-Market

Aggregate cattle supply at the stockyards responded to past prices. During this period, cattle production was concentrated in the Midwest. Figure 2 displays the spatial distribution of cattle in 1910. Illinois, Wisconsin, Iowa, and Kansas had the highest cattle density. About 85% of beef steers shipped to Chicago stockyard were fattened by feedlot farmers in the “corn belt” (Clemen, 1923).

Small feedlot farmers shipped live cattle to stockyards, where they were sold on the spot-market. Proximity to stockyards allowed these farmers to respond quickly to price fluctuations when making their shipment decisions. In a 1905 report, the Bureau of Corporations noted “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).
The stockyard markets were composed of inelastic, price-taking sellers and the monopsonistic meatpacking cartel. Chicago’s Union Stock Yards, for example, received on average nearly 10,000 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. It cost between $4.43 and $8.03 to ship a steer from a feedlot in Kansas to Chicago, while average profit per head was $12.70 over the same period (Skinner, 1912). Therefore, cattlemen were reluctant to take their cattle off the market once they arrived at the stockyards.

The spot-market trading environment was conducive to collusion among the meatpackers. Livestock trading occurred in the open market, where packers could directly observe the realized quantity and prices of other buyers (see Appendix Figure 6). In other words, cartel members could easily monitor compliance with their collusive agreements at little cost.

There was a large alternative market for live cattle beyond the stockyards. Figure 3 plots the distribution of the share of cattle in the stockyards purchased by the cartel. On average, 15% of cattle shipped to the stockyards were not sold on the spot-market. Rather, cattlemen, unhappy with the spot-market conditions, would forward their livestock to be sold in the outside market. In 1909, slaughtering and meatpacking establishments processed 59.6% of all cattle slaughtered

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9This cost covers the freight ($0.25-$0.55 per 100 pounds), as well as feed along the route, driving the cattle from feedlot, and loading them onto rail cars. Andrews (1908).

10In fact, the quantity purchased by each packer was published in livestock trade journals (see Appendix Figure ??). Also, the meatpackers built their slaughtering and packing plants adjacent to the stockyard to minimize the travel distance from market to production line. Appendix Figure 8 is a map of Chicago Union Stock Yards; it shows that all the major packing plants were located next to the stockyard.
for food in the United States (1909 Census of Manufactures). The rest were processed on-farm or in retail slaughterhouses near urban markets.\footnote{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).}

Figure 3: Percentage of Cattle Purchased by the Big Five at Stockyard

Note: Data are from *The National Provisioner*.

2.3 Refrigerated Beef Production

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, in the slaughtering and meatpacking sector, wages and salaries accounted for only 5.4% of total production cost, while nonfuel 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 hours of work. Instead, they received hourly wages to “work until the day’s killing is done” (Commons, 1904).

2.4 Two Phases of Cartel Strategies

Between 1893 and 1918, the Big Five formed a cartel that controlled both the live cattle market and wholesale beef market. In 1913, regulatory changes forced the cartel to switch from a dynamic manipulation strategy to a static non-manipulation strategy.
Phase 1: Cartel Used Dynamic Strategy to Manipulate the Livestock Market

Between 1893 and 1912, the cartel used dynamic strategies to manipulate the livestock market. Though the Sherman Act was passed in 1890, enforcement against anticompetitive practices was lax.\textsuperscript{12}

In the livestock wholesale market, the cartel not only fixed the market share and charged the same price but also used its market power to manipulate cattle prices to gain more than a monopsony. The strategy is best summarized by Circuit Judge Peter Grosscup in a 1903 case:\textsuperscript{13}

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 (\textit{Swift & Co. v. United States}, 196 U.S. 375). In the majority opinion, Justice Oliver Wendell Holmes wrote:

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 courts issued injunctions against certain anticompetitive behaviors in the aforementioned cases, the injunctions were weakly enforced and they had no explicit restriction against potential price manipulation. Eventually, despite abundant evidence on their collusive behavior, the grand jury found the packers and their executives not guilty of all criminal charges under the Sherman Act.\textsuperscript{14}

\textsuperscript{12}In the 1894 case \textit{United States v. E.C. Knight Co.}, the Supreme Court ruling exempted manufacturing from “interstate commerce” restrictions, effectively barring the federal government from pursuing antitrust action against manufacturing firms under the Sherman Act. In 1898, in \textit{Hopkins v. United States}, the court held that livestock trade occurring at the Kansas City stockyards did not constitute interstate commerce; this ruling further restricted application of the Sherman Act to the livestock market (\textit{Walker, 1910}).

\textsuperscript{13}\textit{United States v. Swift & Co.} (122 F 529).

\textsuperscript{14}Evidence admitted by the court include 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. (\textit{The National Provisioner}, March 9, 1912.) The consensus among contemporary newspapers and historians later was that jurors were reluctant to impose criminal penalties upon the socially prominent defendants, whereas only civil charges were brought in the previous antitrust cases against industry giants (\textit{Lamoreaux, 2019}).
Phase 2: Cartel was Forced to Adopt Static Strategy

The packers, however, decided the weekly meetings had become too risky to continue given the new legal landscape. In particular, new rulings against Standard Oil and American Tobacco made the packers legally more vulnerable in the ensuing civil case (Yeager, 1981).

The packers decided to suspend the weekly meetings and returned to the fixed market-share agreement to avoid future prosecutions. By the end of January 1913, after a few rounds of negotiation, the packers had agreed on the percentage of livestock purchases and suspended the weekly meetings (Federal Trade Commission, 1919). The market-share agreement operated without frequent communications to manipulate the market, thus is consistent with the standard static monopsony cartel model. In other words, the cartel followed the "Dynamic Strategy" until January 1913, after which it was forced to adopt the "Static Strategy". The historical setting provides unique observations of the market outcomes with the same set of participants under different cartel strategies.

3 Data

I collected weekly livestock market data from historical trade journals to quantify the effect of the dynamic cartel manipulation. These data cover the four largest stockyards from 1903 to 1917. Figure 4 shows where the data lie on the overall time frame. To analyze the decisions of both the cattlemen and the cartel, I combined this livestock market data with information on input cost and downstream sales.

Figure 4: Event Timeline and Data Coverage

15 The packers met under the cover of a "board meeting" for a joint holding company, the National Packing Company. In 1913, the packers dissolved the holding company and stopped the weekly "board meeting".

16 The packers maintained their market-share agreement until 1920, when they were eventually forced to divest the production chain under a consent decree.
3.1 Livestock Market Data

I collected weekly cattle trade data from *The National Provisioner* for 1903 to 1917 on the four largest stockyards: Chicago, Kansas City, St. Louis, and Omaha. This trade journal published weekly data on the number of cattle shipped into the stockyards, the number of cattle that left the stockyards. The difference between the two is thus the number of cattle slaughtered (i.e., purchased by the cartel). The weekly data also include wholesale cattle prices,\(^{17}\) as well as wholesale refrigerated beef prices in New York City. These data allow me to directly measure cattlemen's aggregate shipment decision as well as the cartel's input quantity and price. The weekly publication also noted cases in which transactions were affected by exogenous events such as disease quarantine or extreme weather. I exclude all such cases from my analysis. Appendix A provides details on variable construction and validation.

Table 1 provides the summary statistics of the cattle market. On average, more than 9,000 head of cattle a day were shipped to the 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 they were all dominated by the same packers.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago</td>
<td>17.12</td>
<td>16.45</td>
<td>16.31</td>
<td>18.51</td>
<td>16.79</td>
</tr>
<tr>
<td>Kansas City</td>
<td>(2.63)</td>
<td>(2.62)</td>
<td>(2.45)</td>
<td>(1.79)</td>
<td>(2.59)</td>
</tr>
<tr>
<td>Omaha</td>
<td>9.36</td>
<td>6.78</td>
<td>3.45</td>
<td>3.50</td>
<td>6.58</td>
</tr>
<tr>
<td>St Louis</td>
<td>(2.27)</td>
<td>(2.72)</td>
<td>(1.29)</td>
<td>(1.47)</td>
<td>(3.27)</td>
</tr>
<tr>
<td>Total</td>
<td>5.52</td>
<td>4.19</td>
<td>2.22</td>
<td>2.48</td>
<td>4.02</td>
</tr>
<tr>
<td>Average daily</td>
<td>(1.44)</td>
<td>(1.55)</td>
<td>(0.82)</td>
<td>(1.13)</td>
<td>(1.89)</td>
</tr>
</tbody>
</table>

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

Cattle supply exhibits large variations from week to week. Figure 5 displays the average daily shipment for each stockyard. The cattle supply exhibits obvious seasonality, driven by the natural production cycle of cattle. The supply also varied widely from week to week.\(^{18}\) In other words, the aggregate supply at the stockyard spot-market can be drastically different from one week to the next, even for cattle fattened over the same period with similar feed costs.

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\(^{17}\) Appendix Figure ?? shows examples of the weekly publication.

\(^{18}\) The coefficient of deviation for the average shipment is 0.49.
Spot-market prices for cattle also varied dramatically from week to week (see Figure 6). As a benchmark, the average profit margin per head of cattle is $12.80 in 1909 (University of Illinois at Urbana-Champaign Agricultural Experiment Station, 1912). Thus, a $0.25 drop in the wholesale price would wipe out 30% of a cattleman’s net profit.
3.2 Auxiliary Data

I collected weekly wholesale prices of live hogs in New York City from the *The National Provisioner*. I consider this as a close substitute for refrigerated beef that was not influenced by the cartel.\(^{19}\) 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; therefore, I use them as instrumental variables to estimate the supply parameters.

To control for cost factors of cattle production, I collected monthly wholesale corn and hay prices from the *Chicago Board of Trade Annual Report*.\(^{20}\) To measure weather shocks, I constructed the area-weighted average of monthly temperature and precipitation using the county-level historical data from Bleakley and Hong (2017).

I used the 1917–1919 cost of living survey\(^{21}\) to estimate the retail demand for beef and other food items. This 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 6.2, I discuss how I constructed the data for demand estimation.

4 Descriptive Evidence of the Dynamic Cartel Strategy

Using high-frequency data covering the market with and without frequent cartel communication, I can empirically document the market outcomes under different cartel strategies. In this section, I first quantify the aggregate market effect of the manipulation coordinated through the weekly meetings. I then show that the main difference between the two periods is whether cattlemen could correctly predict market prices. This difference provides the basis for identification in Section 6.

4.1 Dynamic Manipulation Is Effective

I first use an event-study design to examine how the changes in cartel strategy influences aggregate market outcomes. Exogenous shifts in the external legal environment forced the cartel to adjust the market strategy while other aspects of the market remained the same. It is thus plausible to attribute the difference in aggregate outcomes to the changes in cartel strategy.

Specifically, I estimate the event-study regression

\[
y_{kt} = \alpha_1 \mathbb{1}(\text{Dynamic Period}_{1903-1912}) + X_{kt} + \eta_{kw} + T + \epsilon_{kt}
\]

where \(y_{kt}\) is the outcome variable for stockyard \(k\) at time \(t\); \(\eta_{kw}\) is the stockyard-by-week-of-the-

\(^{19}\)The cartel also produced cured meats, as well as refrigerated (dressed) lamb and pork, etc. Though these animal products are close substitutes, their prices cannot be a plausible instrument.

\(^{20}\)Specifically, I use the No.2 Corn and No.1 Baled Timothy Hay prices. (*Chicago Board of Trade, various years*)

\(^{21}\)Bureau of Labor Statistics (1992). The data is digitized by the Inter-university Consortium for Political and Social Research (ICPSR) and available as ICPSR study 8299.
year fixed effect, which captures the seasonality of the cattle market at each stockyard; \( T \) is the yearly time trend; \( X_{kt} \) includes lagged weather shocks, lagged input prices, as well as the monthly temperature and precipitation of the counties where the stockyards were located. \( \alpha_1 \), the event-study coefficient, represents the average difference of the outcome \( y_{kt} \) between the dynamic manipulation and static non-manipulation period. Because of the small number of stockyards, I follow Bertrand, Duflo, and Mullainathan (2004) and allow for the presence of arbitrary correlations within each market over time by clustering standard errors by stockyard.\textsuperscript{22}

Table 2 shows that market manipulation was effective. During the dynamic manipulation period, 17% more cattle were shipped to the stockyards, while the cartel price was 4% lower. Cattlemen’s margin, defined as the difference between the wholesale cattle and corn prices, was 24% lower.

<table>
<thead>
<tr>
<th></th>
<th>(1) Total Shipment</th>
<th>(2) Price</th>
<th>(3) Cattlemen’s Margin</th>
</tr>
</thead>
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<tr>
<td>Dynamic Period Dummy (03/1903-01/1913)</td>
<td>0.920* (0.335)</td>
<td>-0.728* (0.264)</td>
<td>-1.128** (0.242)</td>
</tr>
<tr>
<td>Time Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Weather Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cost Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Mean</td>
<td>5.30</td>
<td>18.66</td>
<td>4.72</td>
</tr>
<tr>
<td>% wrt Mean</td>
<td>17.34</td>
<td>3.90</td>
<td>23.89</td>
</tr>
<tr>
<td>Observations</td>
<td>2461</td>
<td>2103</td>
<td>2110</td>
</tr>
<tr>
<td>Adjusted R-S CLOSED</td>
<td>0.85</td>
<td>0.75</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Note: “Cattlemen’s Margin” is defined as the difference between cattle price and input cost, which is approximated by the three-month lagged corn price. “% wrt Mean” shows the the estimated coefficient of the manipulation period dummy (first row) as a percentage of the variable’s sample mean during the non-manipulation period. Time controls include stockyard-by-week fixed effects and yearly trend. 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 No.4 corn and hay prices at the Chicago Commodity Exchange. The data exclude period when the stockyards were closed due to quarantine or extreme weather. 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,\textsuperscript{23} the competitive structure at the wholesale livestock market remained unchanged. Therefore, I assume the market behaved the same during this period.\textsuperscript{24} In addition column (3) of Table 2 directly addresses the

\textsuperscript{22}One obvious alternative is block bootstrap. However, as noted in Bertrand, Duflo, and Mullainathan (2004), block bootstrap performs well when the number of groups is large. This paper uses data from only four stockyards, thus rendering block bootstrap ineffective.

\textsuperscript{23}Agricultural production increased steadily during the second half of the 1910s to satisfy robust export demand (Henderson et al., 2011).

\textsuperscript{24}I explicitly control for the production cost of cattle. I use the price of corn and hay to approximate the input cost in
concern about rising price levels caused by the war. Though this is an event study, column (3) 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.

4.2 Cattlemen Behave Differently Under Static and Dynamic Strategies

As the narrative evidence in Section 2 suggests, the cartel benefited from manipulating the total supply of cattle at the stockyard from week to week. 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 realized market price and total shipments into the stockyards, controlling for seasonality, production shocks, and general time trend. Specifically,

\[ p_{kt} = \alpha_z Z_{kt} + X_{kt} + \eta_{kw} + \tau_y + \epsilon_{kt} \]  

where \( p_{kt} \) is the realized cattle price for the week \( t \) in stockyard \( k \); \( Z_{kt} \) is the number of cattle shipped to the stockyard; \( \eta_{kw} \) is the stockyard-by-week-of-the-year fixed effect, and \( \tau_y \) is the year fixed effect.\(^{25}\) \( X_{kt} \) include the same set of weather and cost controls as in (1). Note that cattlemen made the shipment decisions before they observed the market price for the week. Therefore, \( \alpha_z \) captures whether cattlemen’s shipment decisions are “correct”: if they correctly predicted the market condition and shipped more cattle when the market price turned out to be high, one would expect \( \alpha_z \) to be positive.\(^{26}\)

Table 3 shows the estimation for \( \alpha_z \) under different cartel strategies. The first two columns cover the dynamic manipulation period; the estimated coefficient suggests that the total number of cattle arriving at the stockyards during the dynamic manipulation period did not correlate with the realized market price. When the cartel stopped manipulating the price, however, 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 by 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 dynamic 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
cattle production. One can view this as an approximation for the actual cost of feed, or as the opportunity cost of raising cattle instead of growing grains.

\(^{25}\)In the event-study regression, I include only the year trend because of the dummy variable for the dynamic manipulation period. In regression (2), because I estimate the results for dynamic manipulation and static non-manipulation periods separately, I can include year fixed effects to control for potential nonlinear changes in the trend.

\(^{26}\)Limited by the small sample size, I opt to compare the average values for the two periods, rather than conducting a event-study by year.
Appendix Table 2 show that cattlemen behaved the same in both the first and second half of the dynamic strategy period. Results from the main specification in Table 3 is also robust to restricting the sample to cases with at least three operating stockyards.

### Table 3: Price vs. Shipment

<table>
<thead>
<tr>
<th>Dependant Variable: Price</th>
<th>Dynamic Strategy</th>
<th>Static Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Daily Average Shipment (000s)</td>
<td>-0.007 (0.034)</td>
<td>0.042 (0.029)</td>
</tr>
<tr>
<td>Time Controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Weather Controls</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Cost Controls</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>1328</td>
<td>1320</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.75</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Note: 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 No.4 corn and hay prices at the Chicago Commodity Exchange. The data exclude cases when the stockyards were closed due to quarantine or extreme weather or when less than two days of trading data were reported. Standard errors are clustered by stockyard. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

### 4.3 Cartel Members Did Not Deviate

The observed cartel outcome during the static period coincides with the optimal cartel strategy only if cartel members did not cheat. Past research shows that cartels may have used frequent meetings also to resolve other disagreements among the members (Genesove and Mullin, 2001). Therefore, suspending the weekly meetings may cause potential deviation from the collusive agreement and thus sub-optimal cartel outcomes.

To show that cartel members did not deviate under the static strategy, I test whether the observed market share among the packers remained unchanged during the static period. The analysis uses data of cattle purchases by each cartel member at the Kansas City Stockyard, which has the longest data series of firm purchases that covers both the dynamic and static periods.

Specifically, I estimate the coefficients for the year dummies $\alpha_y$ in

$$s_{ft} = \sum_{y=1907}^{1917} \alpha_y I(Year = y) + \epsilon_{ft}$$

where $s_{ft}$ is the market share of firm $f$ in year $t$.

---

$^{27}$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.
Figure 7 plots the estimated coefficient. Despite large week-to-week fluctuations in aggregate market supply, relative market share among the Big Five remained constant throughout the whole period. This suggests that cartel members did not deviate from their collusive market-share agreement after they suspended the weekly meetings. This is consistent with the narrative evidence described in Section 2.2: the stockyard environment made it hard for cartel members to cheat even without frequent meetings. Cartel members could directly observe the quantity purchased by other packers and the price they paid.

Figure 7: Cartel Members Did Not Deviate

Note: The graph plots the coefficient for year dummies in (3). The vertical bars denote 95 percent confidence intervals.

5 Analytical Framework of the Cattle Spot-Market

In this section, I present a structural model of spot-market cattle supply and cartel demand under static monopsony. Though results from the event study provide an arguably causal estimate on the effect of the dynamic cartel strategy on input market price and quantity, it 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 the markdown. Therefore, I developed the structural model to estimate what would happen during the dynamic period if the cartel were to adopt a static strategy. The main goal is to quantify the effect of dynamic cartel manipulation by comparing the empirical outcomes with the counterfactuals under static cartel strategy.

On the supply side, cattlemen make spot-market supply decisions following a discrete choice model: cattlemen choose between selling to the cartel and selling to the competitive market outside of the stockyard.\(^{28}\) I use the standard logit choice model to capture cattlemen’s sales deci-

\(^{28}\)I assume the outside market to be perfectly competitive and thus do not consider the case of umbrella damage, where the outside non-cartel buyers adjust their pricing to the supra-competitive level set by the cartel at the stockyard.
sions. On the demand side, I specify the static cartel problem: the cartel chooses the quantity of cattle, facing both upward-sloping input supply and downward-sloping demand, as it was also the monopoly seller of refrigerated beef.

I estimate downstream demand faced by the cartel separately, with the Almost Ideal Demand System. I then combine the spot-market supply and downstream retail demand to characterize the cartel’s equilibrium static strategy for counterfactuals.

This modeling choice is driven primarily by the historical market setting. Regulatory changes forced packers to adopt the static strategy, without changing any other aspects of the market. This allows me to directly estimate the static equilibrium with observed market outcomes under the static strategy. One intuitive alternative would be to specify the model under the dynamic strategy. However, the equilibrium solution under the dynamic strategy requires strong assumptions on how cattlemen and the cartel formed their expectations on the future market. Instead, leveraging the historical setting, I focus on solving the model under static conditions and use the estimated static model to derive the counterfactuals. This approach is effective for estimating the scope and severity of cartel damages, though it is less informative about the specific mechanism of the cartel manipulation.

5.1 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. For cattlemen $i$, he chooses between buyers $j$: $J = \{\text{cartel, outside}\}$. 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 market.

The utility for cattlemen $i$ depends on price $p_{jt}$, observed buyer characteristics $X_{jt}$, latent characteristics $\sigma_{jt}$ and an idiosyncratic utility shock $\epsilon_{ijt}$. Examples of observed characteristics $X_{jt}$ includes weather, lagged cost factors such as feed price, as well as seasonality. $\sigma_{jt}$ represents unobserved (by econometrician) buyer characteristics, including potentially faster payment from a particular buyer, that can correlate with price. This is the potential source of endogeneity problem in the model. Finally, $\epsilon_{ijt}$ is a random utility shock identically and independently distributed across sellers and choices over time. An example of this utility shock could be market rumors of spreading bovine tuberculosis or pending government inspections\textsuperscript{29}, which may temporarily shift his sales decision. This i.i.d assumption is reasonable for the static period, when both the cartel and cattlemen were making decisions to maximize the static per-period gain. Under dynamic cartel strategy, because the cartel chose the current price to influence future supply responses, the error term may likely to be correlated across time.

\textsuperscript{29}Bovine tuberculosis and the corresponding quarantine requirement were in fact the two major causes of market closure during this period.

---

\textsuperscript{This is plausible given the large number of small buyers outside the stockyard who competes in prices.}
In other words, cattleman \( i \)'s utility when selling to buyer \( j \) is:

\[
U_{ijt} = \gamma p_{jt} + X_{jt} \gamma_x + \sigma_{jt} + \epsilon_{ijt} \tag{4}
\]

Suppose that \( \epsilon_{ijt} \) follow an extreme value distribution, and normalize the utility derived from the outside market to be zero. This generates the standard logit form of the market-share expression

\[
\ln(S_{\text{cartel},t}) - \ln(S_{\text{outside},t}) = \gamma p_{\text{cartel},t} + X_{jt} \gamma_x + \sigma_{\text{cartel},t} \tag{5}
\]

where \( S_{\text{cartel},t} \) is the share of cattle at the stockyard purchased by the meatpacking cartel, and \( S_{\text{outside},t} \) is the share of cattle left the stockyard alive to be sold in an outside market. (5) suggests that the supply side of the structural model can be estimated using a simple instrument variable approach.

Of the \( Z_t \) cattle arrived at the stockyard, the cartel can expect to purchase \( q(p_t) \) head at a given price \( p_t \), where

\[
q(p_t) = \frac{\exp(\gamma p_{\text{cartel},t} + X_{jt} \gamma_x) + \sigma_{\text{cartel},t}}{1 + \exp(\gamma p_{\text{cartel},t} + X_{jt} \gamma_x) + \sigma_{\text{cartel},t}} Z_t \tag{6}
\]

### 5.2 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, \(^{30}\) or

\[
m_t = \min\{\theta_1 q_t, \theta_2 v_t\} \tag{7}
\]

I further assume that there is no productivity difference across firm. Because the production process relied primarily on manual labor and all the packers drew from the same local labor market, it is likely that all firms share the same “conversion rate” between cattle and beef. In other words, all the cartel members share the same \( \theta_1 \). Finally, because cattle accounted for more than 90% of the variable cost, the analysis focuses only on the cost of cattle and abstract away from all other cost such as labor or fuel. With these two assumptions, 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 (6).

Because the cartel is also a monopolist seller of refrigerated beef, it faces a downward-sloping

\(^{30}\)For reference, a 1,200-pound steer yields a 750-pound carcass, or 63% of the input weight.
demand curve $D(.)$. Under the static strategy, the cartel chooses optimal price $p^*_t$ at the cattle wholesale market to maximize per-period profit:

$$p^*_t = \arg\max_{p_t} D(m(p_t))m(p_t) - c(p_t)$$  \hspace{1cm} (8)$$

5.3 Equilibrium

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

**Definition 1.** 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 (6) and the price solves the cartel’s profit-maximization problem in (8).

5.4 Alternative Dynamic Model

The analysis abstracts from discussing cattlemen’s shipment decisions and focuses primarily on the spot-market, where cattlemen interacted with the cartel. The primary goal is to quantify the distortion created by the dynamic cartel strategy, while taking the empirical aggregate market supply and spot-market elasticity as given. One obvious alternative is to extend the supply side to incorporate cattlemen’s dynamic shipment decisions, where the cattlemen observed past market information and decided whether to ship to the stockyard market for each period.

However, two factors make this approach less desirable. First, to estimate the dynamic choice of cattlemen, one would need to observe the total number of cattle available for sales, the actual amount shipped to the stockyards, and the amount shipped to outside markets or held back for the next period. Other than the shipment to stockyards, other data were not available, neither at the weekly level nor at less frequent time intervals. Second, it requires an explicit belief structure to solve for the equilibrium under the dynamic cartel strategy. Section 4 suggests that cattlemen’s behavior was not consistent with rational expectations, yet scant evidence exists to support any specific belief forms.

The historical setting allows me to analyze the effect of cartel manipulation without estimating the dynamic decisions on either the cattlemen or the cartel. The drawback of this approach is that the counterfactual results are of a partial equilibrium nature: they do not account for the changes in total supply to stockyards or aggregate cattle production under the static strategy. However, because the wholesale market price of cattle would be higher under the static cartel strategy, supply to the stockyards and aggregate production would both be higher than the observed value during the dynamic manipulation period. Therefore, the counterfactual results that take the empirical supply and production levels as given correspond to a lower bound of the effect of the cartel strategy on the input market.
6 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.

6.1 Spot-Market Supply

As discussed in Section 5.1, estimating spot-market elasticity with observed market share and price data faces the typical simultaneity problem in industrial organization: the unobserved market shock $\sigma_{jt}$ may influence both market price $p_{jt}$ and cartel demand.\(^{31}\) A demand shifter can be used as an instrument for price to identify the spot-market supply function. Because the volume of cattle purchased by the cartel is influenced by the downstream demand for refrigerated beef, I use the price of beef substitutes to instrument for cattle prices at the cartel level. 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, in addition to 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.\(^{32}\)

Table 4: Spot-Market Supply

<table>
<thead>
<tr>
<th></th>
<th>Dynamic Strategy</th>
<th></th>
<th>Static Strategy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td></td>
<td>OLS</td>
<td>IV</td>
<td>OLS</td>
<td>IV</td>
</tr>
<tr>
<td>Cattle Price</td>
<td>-0.02</td>
<td>0.01</td>
<td>-0.04</td>
<td>0.13**</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.05)</td>
<td>(0.04)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Observations</td>
<td>1087</td>
<td>644</td>
<td>610</td>
<td>492</td>
</tr>
<tr>
<td>First Stage F-statistics</td>
<td>40.32</td>
<td></td>
<td>39.31</td>
<td></td>
</tr>
</tbody>
</table>

Note: The table shows the regression coefficient $\gamma_p$ described in equation (5). The dependent variable is $\ln(S_{cartel,kt}) - \ln(S_{outside,kt})$. All estimations include the same set of time, weather, and cost controls. The sample excludes the top and bottom 1% of observations. Live hog price in New York City is used as instrument. Standard errors are bootstrapped with 100 iterations. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 4 presents the estimated coefficient for $\gamma_p$, estimated separately for the dynamic and static period. Without taking into account the price endogeneity, the OLS estimates for the price

\(^{31}\)One example of such shocks is railroad accidents, which influence both shipment of live cattle to outside markets and the cartel’s productivity.

\(^{32}\)Bertrand, Duflo, and Mullainathan (2004) suggests use block bootstrap by re-sampling the groups of observation when the number of groups is large, yet the data contains 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 simultaneous for all four stockyards.
coefficients are not statistically different from zero. Column (4) presents the result for static period using the instrumental variable approach. After addressing the endogeneity problem, the estimated price coefficient becomes 0.13.

Note that the estimated price coefficients are small and statistically insignificant under the dynamic strategy. This is driven by potential estimation bias for the dynamic period. As discussed in Section 4.2, 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 panel estimation.

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

6.2 Cartel Demand

I estimate the demand for beef $D(.)$ separately using the Almost Ideal Demand System (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. Appendix A reports the specific items included in each category.

This modeling choice is appropriate from both conceptual and practical perspectives. As a wholesaler, the cartel cared about the general demand for beef with respect to other food items such as pork. AIDS model is a good first-order approximation for these broad product categories. In addition, the AIDS model captures households’ consumption behaviors and 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 dynamic strategy on urban consumers.

Table 5 summarizes the general household consumption pattern from the data. Among the 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

---

33See Appendix B for details of the two-stage budgeting process for estimation.
34The 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.
of beef per year, four times the quantity of pork. For comparison, in 2017, Americans consumed 54 pounds of beef per person, or 216 pounds of beef per year for a family of four. Though the survey data contain household-level information, the reported prices on the household level exhibit little variation. 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 micro data.

Table 5: Summary Statistics of Household Expenditure Survey

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Household expenditure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main food groups (meat, dairy, starch, vegetables)</td>
<td>319.36</td>
<td>100.49</td>
</tr>
<tr>
<td>All food (includes coffee, candy, etc)</td>
<td>544.37</td>
<td>149.66</td>
</tr>
<tr>
<td>Total expenditure by the household</td>
<td>1419.45</td>
<td>394.84</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly wage rate of husband</td>
<td>26.61</td>
<td>8.25</td>
</tr>
<tr>
<td>Household total earnings</td>
<td>1434.04</td>
<td>411.38</td>
</tr>
<tr>
<td><strong>Annual total consumption (lbs.)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>168.11</td>
<td>108.38</td>
</tr>
<tr>
<td>Pork</td>
<td>41.37</td>
<td>54.73</td>
</tr>
<tr>
<td>Poultry</td>
<td>23.37</td>
<td>34.31</td>
</tr>
</tbody>
</table>


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 and contributed to half of total household expenditure on meat products. Among the four food categories, households allocated around a third of their food expenditure each to meat, dairy and starch (e.g., flour, rice, pasta). 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 cent per pound for beef rib, 32 cents per pound for pork tenderloins.

---

36In many cases, the implied price of a certain product is identical across all households within a city. This suggests that the surveyor may have imputed total cost or quantity variables using a fixed price.
37The National Provisioner, April 6, 1918, page 44.
Table 6: Summary Statistics for Prices and Market Shares

<table>
<thead>
<tr>
<th></th>
<th>Price ($/lb)</th>
<th>Expenditure Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (1)</td>
<td>SD (2)</td>
</tr>
<tr>
<td><strong>Meat Products</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>0.29</td>
<td>0.04</td>
</tr>
<tr>
<td>Pork</td>
<td>0.36</td>
<td>0.08</td>
</tr>
<tr>
<td>Poultry</td>
<td>0.35</td>
<td>0.04</td>
</tr>
<tr>
<td>Other (fish, cured meat)</td>
<td>0.36</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>Food Segments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meat</td>
<td>0.31</td>
<td>0.03</td>
</tr>
<tr>
<td>Dairy</td>
<td>0.21</td>
<td>0.03</td>
</tr>
<tr>
<td>Starch</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>Vegetable</td>
<td>0.05</td>
<td>0.01</td>
</tr>
</tbody>
</table>

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. Suppose regional prices reflect local cost factors such as wages and transportation; they are correlated with city-level prices but uncorrelated with unobserved demand shocks and can therefore be a valid instrument.  

Table 7 reports the compensated own-price and cross-price elasticity for the lower-level. The own-price elasticity for beef estimated at the mean is -1.42, which is within the range of other own-price elasticity of beef from other studies. Demand for other meat items appears to be more elastic, which may reflect a general preference for beef, as households spent half of their meat budget on beef.

---

38 The survey questionnaire asked for 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 variation in price can be explained by time. I report the analysis of variance of prices in Appendix Table 3. As shown in columns (4) and (5), a significant fraction of the total variance in prices can be attributed to regional variation.

39 See Appendix Table 4 for elasticity estimation of the upper level.

40 Price elasticity ranges from -0.998 in the U.S. in 1993 (Kinnucan, Xiao, and Hsia, 1996) to -1.19 in the 1970s (Eales and Unnevehr, 1993), to -1.95 in post-WWII Australia (Murray, 1984).
Table 7: Lower-Level Price Elasticity

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

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

6.3 Model Fit

Because I do not impose equilibrium assumption of the cartel behavior for the estimation, one concern is that the prediction may not match the observed cartel strategy. Though there is no evidence of deviation on the input market after the cartel suspended the weekly collusive meetings, as discussed in Section 4.3, there is no direct evidence on whether they still behave collectively as a monopoly seller on the wholesale market. In addition, there may be operation frictions 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 static period. Appendix Figure 1 plots the predicted cartel quantity against the observed purchase. The predicted values largely replicates the distribution of the actual quantity observed in the data. In other words, the cartel behavior after 1913 is consistent with the classic static model. There are a few cases where I observe more than 8,000 daily purchase and the model predicted a lower cartel quantity. These outliers all occurred at the Chicago stockyard during the winter months of 1916, which suggests that there were potential unobserved shocks in the market for this particular period that were not captured in the model.

7 Counterfactuals

To quantify the effect of dynamic monopsonistic market manipulation, I use the estimated model to simulate counterfactual outcomes for the cattle spot-market and the downstream wholesale beef market for the dynamic period. I first quantify the effect on the wholesale cattle market price and quantity by comparing the observed market outcome under the dynamic cartel strategy with the counterfactuals under a static monopsony. In addition, from a policy perspective, antitrust regulators may also care about how disrupting cartel manipulation could influence downstream consumers. Therefore, I also 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 distribu-
tional effect on individual sellers and buyers.

7.1 Solving for Counterfactual Equilibrium

Following the equilibrium definition in Section 5.3, I find the counterfactual equilibrium price by solving (8). Cartel’s optimal decision 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 requires two main components: the parameters $\gamma_p$ and $\gamma_x$, and the total supply of cattle at the market $Z_t$. $\gamma_p$ and $\gamma_x$ are estimated from the static period in Section 6.1. I use the observed cattle shipment during the dynamic period for $Z_t$. I solve for the optimal cartel price, as described in (8), by numerically finding the value that maximize the profit function.$^{41}$ I then calculate the corresponding counterfactual cartel quantity using the inverse supply defined in (6).

This counterfactual is of partial equilibrium in nature: 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 dynamic cartel strategy: absent cartel manipulation, the cattle wholesale 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.

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

7.2 The Livestock Market Suffered Larger Losses Under Manipulation

The cartel’s dynamic manipulation strategy reduced the spot-market price and the total quantity traded at the stockyards. Figure 8 presents the distributions of observed and counterfactual wholesale cattle prices and quantities. Comparing with the observed market price, average cattle wholesale price would be 23.4% higher in the counterfactual scenario, or $43.9 per head.$^{42}$

$^{41}$The average price for cattle was between $10 and $25 (see Figure 6). For the solution, I use the interval (0,50) to search for the optimal price.

$^{42}$The average price is $3.66 lower. For a cattle of 1,200 lb, this implies a $43.9 increase.
comparison, cattlemen’s average profit in 1909 was $28.\textsuperscript{43} Interrupting the dynamic manipulation can increase the profit margin by 57% for cattlemen.

Meanwhile, 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. Assume the urban beef supply adjust by the same percentage. Given that the average household consumed 168 pounds of beef per year (see Table 5), this also implies that the average household consumed 23.3 pounds more of beef per year absent of the cartel manipulation.

![Figure 8: Counterfactual and Observed Cattle Prices and Quantities](image)

(a) Cartel Price  
(b) Cartel Quantity

### 7.3 Heterogeneity across Markets

The dynamic 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 \( X_{jt} \), which includes local weather conditions and stockyard-by-week 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 as Chicago were less influenced by the dynamic strategy. On average the observed price in Chicago is 93% of the counterfactuals, while the ratio is below 80% for all the other three stockyards. Meanwhile, Chicago also has the smallest quantity changes under the counterfactual scenario.\textsuperscript{44} Intuitively, Chicago is a major transit hub with easier transportation to outside markets. There were also a large number of feedlot farmers near Chicago (see

\textsuperscript{43}See Skinner (1912). All dollar values are adjusted to 1920 dollars.  
\textsuperscript{44}Appendix Figure 2 and Appendix Figure 3 plot the complete distribution of counterfactual prices and quantities by stockyard.
Figure 2) who were less affected by the high shipping cost. These factors all limited the cartel’s market power over the sellers and thus less distortion.

Table 8: Empirical and Counterfactual Market Outcomes by Stockyard

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

Note: Table presents the average values by city. Standard deviations are in parenthesis.

7.4 Manipulation Increased Beef Prices and Household Food Expenditure

Next, I compare the effect of dynamic cartel manipulation in the cattle market on downstream wholesale refrigerated beef prices. Under a static strategy, the cartel purchased more cattle at the input market, which led to lower prices for refrigerated beef 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. Panel (a) in Figure 9 shows the distribution of counterfactual and observed beef prices. If the cartel switched from the dynamic manipulation to the standard static 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. This back-of-the-envelope calculation, however, under-states 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 dynamic strategy, $p_s$ the counterfactual prices under the static 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. I assume perfect competition in other agricultural product markets so that their prices do not respond to changes in the cartel strategy. For the calculation, I use the reported New York City beef price in

---

45 The difference between the two expenditures is the compensating variation (CV), defined as $CV = E(u_o, p_s) - E(u_o, p_o)$. Appendix Figure 4 shows the distribution of observed and counterfactual expenditures used to construct the compensating variation.
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.

The panel (b) of Figure 9 shows that, in the static counterfactual, 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 limited the cartel’s ability to charge higher prices. The large damage on the upstream cattle market and relatively small effect on downstream urban consumers also reflects the fact that the cattlemen actively pushed to regulating meatpackers’ market power, while consumers were largely absent in this policy discussion.\(^{46}\)

Figure 9: Counterfactual and Observed Beef Price and Total Food Expenditure

![Figure 9: Counterfactual and Observed Beef Price and Total Food Expenditure](image)

(a) Refrigerated Beef Price  
(b) Total Food Expenditure

8 Conclusion

In this paper, I study the effect of dynamic monopsonistic cartel manipulation on the input market. My results show that the dynamic cartel strategy created larger welfare loss than what a typical static monopsony model would suggest. Under its dynamic manipulation strategy, the meatpacking cartel purchased fewer cattle and at lower prices than it would have under a static strategy, while also increasing downstream wholesale beef prices and total household expenditure on food. Regulatory changes imposed on the cartel benefited both upstream cattlemen and downstream consumers, even without breaking up the cartel through forced divestiture.

\(^{46}\)For example, in 1916, ten people in the business were invited to give statements at the house judiciary committee hearing on the investigation of beef industry. Except for one trade journal editor, all the other nine witnesses were cattle ranchers or feedlot farmers. (\textit{House Committee on the Judiciary, 1916})
The historical case has important implications for contemporary markets. Without a functioning contract market, which is often the case in developing countries, small sellers usually rely on spot markets for sales (Chatterjee, 2019). Without effective 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. For policymakers focus primarily on consumer welfare, this can imply low political will to regulate the market.

Finally, by documenting a manipulation strategy that lasted for decades, this paper provides new evidence to support regulations against coordinated market manipulation. Given the prevalence of such behavior (Shiller, 1990; Assenza, Bao, Hommes, and Massaro, 2014), this gap between policy and empirical evidence has significant legal and economic implications. Further research into the prevalence of such manipulation is needed to properly assess cartel damages.
References


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Appendices

A  Data Collection

A.1  Cattle Market

I collected the cattle shipment (including “receipts”, which is the total number of cattle arrived at the stockyards, and “shipment”, the number of cattle left the stockyards) and price data from The National Provisioner. Cattle market data from the trade journal is verified by checking the monthly and annual aggregates against Chicago Union Stockyard Annual Report during the same period.

Though cattle prices are available by type and grade (see Appendix Figure ??), 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. Few Texas cattle were sold in Chicago market, and would either be bought as feeders or as low-quality local butcher meat.

A.2  1917-1919 Cost of Living Survey

The following table summarizes the food items included in each category for the demand estimation:

<table>
<thead>
<tr>
<th>Variables Used in Aggregate Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td><strong>Meat Products</strong></td>
</tr>
<tr>
<td>Beef</td>
</tr>
<tr>
<td>Pork</td>
</tr>
<tr>
<td>Poultry</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td><strong>Food Segments</strong></td>
</tr>
<tr>
<td>Meat</td>
</tr>
<tr>
<td>Dairy</td>
</tr>
<tr>
<td>Starch</td>
</tr>
<tr>
<td>Vegetable</td>
</tr>
</tbody>
</table>
B Demand Estimation

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

\[ \omega_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln \left( \frac{X}{P_s} \right) + \epsilon_i \]  

(9)

where \( P_s \) is the Stone price index defined as

\[ \ln P_s = \sum_i \omega_i \ln p_i \]  

(10)

\( \omega_i \) 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 \( \epsilon_i \) 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

\[ \Sigma \alpha_i = 1; \Sigma \beta_i = 0; \Sigma_i \gamma_{ij} = 0 \forall j \]  

(11)

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

\[ \Sigma \gamma_{ij} = 0 \forall i \]  

(12)

Symmetry: follows from Shepard’s Lemma,

\[ \gamma_{ij} = \gamma_{ji} \forall i, j \]  

(13)

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

\[ \omega_S = \alpha_S + \sum_H \gamma_{SH} \ln p_S + \beta_S \ln \left( \frac{X}{P} \right) + \epsilon_S \]  

(14)

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 (11) to (13) 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:

\[ \epsilon_{ij} = -\delta_{ij} + \frac{1}{\omega_i} (\gamma_{ij} + \beta_i (\alpha_i + \sum_k \gamma_{kj} \ln p_k)) + \omega_j (1 + \frac{\beta_j}{\omega_j}) \]  

(15)

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

Appendix Table 1: Concentration of Refrigerated Beef Production, 1916

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

Note: Data from [Federal Trade Commission (1919)](Federal%20Trade%20Commission). Total number of cattle slaughtered for interstate trade in 1916 was 7.9 million.
Appendix Table 2: Robustness: Prices vs. Shipments

<table>
<thead>
<tr>
<th>Dependant Variable: Price</th>
<th>First and Second Half of Dynamic Strategy Period</th>
<th>Sample with ≥ 3 Stockyards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) 1903-1908</td>
<td>(2) 1909-1912</td>
</tr>
<tr>
<td>Daily Average Shipment (000s)</td>
<td>0.022 (0.019)</td>
<td>-0.010 (0.016)</td>
</tr>
<tr>
<td>Time Controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Weather Controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cost Controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>598</td>
<td>714</td>
</tr>
<tr>
<td>Adjusted R-Sclosede</td>
<td>0.68</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Note: The table shows the regression coefficients $\alpha_z$ 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 No.4 corn and hay prices at the Chicago Commodity Exchange. Data exclude period when the stockyards were closed due to quarantine or extreme weather. 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: Analysis of Price Variance

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

Note: Prices are aggregated up to city level.
### Appendix Table 4: Higher-Level Price Elasticity

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

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

Appendix Figure 1: 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 2: Distribution of Counterfactual and Observed Cartel Price by Stockyards

Note: The value of the counterfactual prices is calculated by solving (8).
Appendix Figure 3: Distribution of Counterfactual and Observed Cartel Quantities by Stockyards

Note: The value of the counterfactual quantity is calculated by solving (8).
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 9 for the distribution of $E(u_o, p_s)$ and $E(u_o, p_o)$. 
Appendix Figure 5: Swift Ice-Refrigerated Rail Car and Ice-Manufacturing Plant
Appendix Figure 6: Buyers at Chicago’s Union Stock Yards, 1909


Appendix Figure 7: Cattle Slaughter Relied Primarily on Manual Labor

Appendix Figure 8: 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.