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Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Christopher Pudenz is PhD Student, Department of Economics, Iowa State University, Ames, Iowa 50014. E-mail: ccpudenz@iastate.edu.

Lee Schulz is Associate Professor, Department of Economics, Iowa State University, Ames, Iowa 50014. E-mail: lschulz@iastate.edu.

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For questions or comments about the contents of this paper, please contact Lee Schulz, lschulz@iastate.edu.

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Multi-plant Coordination in the U.S. Beef Packing Industry

Christopher C. Pudenz and Lee L. Schulz*

Abstract. U.S. beef packers openly began employing multi-plant coordination during the last decade. This paper adapts the Salop Circular City framework to demonstrate that beef packers effectively implementing multi-plant coordination can eliminate intra-firm forces causing correlation between downstream beef prices and upstream fed cattle prices. Taken together with market concentration, geography and transportation cost effects, alternative marketing arrangements, and cattle cycles and related beef packer capacity utilization, multi-plant coordination helps explain farm-to-wholesale beef price spreads that remain wide absent any obvious market shocks. Such beef price spread behavior has been observed in 2021, during which beef prices have been seemingly unhinged from fed cattle prices. We further demonstrate that adding a single strategically-located packing plant, owned by a different firm, can restore the correlation between beef prices and fed cattle prices. Overall, our results have implications for current policy and industry deliberations and also suggest avenues for future research.

Keywords: beef cattle, cattle cycles, farm-to-wholesale price spread, livestock economics, market concentration, multi-plant coordination, packers, policy

JEL Codes: Q02, Q13, Q18

*Pudenz is a PhD student, and Schulz is an Associate Professor, both in the Department of Economics, Iowa State University, Ames, IA, USA.

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1. Introduction

On February 1, 2013, Cargill, Inc. shut down its very large beef processing plant near Plainview, Texas. The permanent closure reduced the company’s steer and heifer slaughter capacity by 4,650 head per day, which represented roughly 4% of U.S. fed cattle capacity at the time (Daily Livestock Report, 2013). Cargill, Inc. (henceforth Cargill) cited tight cattle supplies regionally, and in North America more broadly, as the primary motivation. A Cargill press release read:

Given the over-capacity that exists with four major beef plants in the Texas Panhandle and a dwindling supply of cattle in the region, idling Plainview will allow Cargill to operate its other beef plants in Texas, Colorado and Kansas more consistently on a five-day-per-week basis to meet our customers’ requirements, while helping us maintain our position in the U.S. beef sector (Cargill, 2013).

Cargill was not the only large beef packer to reduce capacity in response to tight cattle supplies. On August 18, 2015, Tyson Fresh Meats announced it would cease operations at its beef slaughter facility in Denison, Iowa, “to better align its overall production capacity with current cattle supplies” (Tyson, 2015a). Steve Stouffer, then-president of Tyson Fresh Meats (henceforth Tyson), said in a statement, “We believe the move to cease beef operations at Denison will put the rest of our beef business in a better position for future success” (Tyson, 2015a). The closure in Denison further reduced U.S. slaughter capacity by an estimated 2,150 steers and heifers per day (Daily Livestock Report, 2015).¹

While troubling to the cattle producers and communities relying on these plants, and easy to criticize given the present-day capacity constraints, these closures were prudent (perhaps even necessary) business decisions at the time. Persistently tight cattle supplies in the mid-2010s drove up fed cattle prices, putting downward pressure on packer profits. Securities and Exchange Commission filings indicate live cattle input costs increased by an astounding $1.1 billion from 2014 to 2015 for Tyson’s parent company Tyson Foods, Inc., and their beef segment reported an operating loss of $66 million in 2015 (Tyson, 2015b).

¹According to Cattle Buyers Weekly, in the mid-2010s, Cargill closed two plants, Tyson closed one plant, JBS S.A. closed no plants, National Beef Packing Company, LLC closed one plant, and American Foods Group, LLC closed one plant. Cattle Buyers Weekly lists no other firms as operating multiple plants.
Considering Tyson Foods, Inc. is a publicly traded company, and executives must answer to investors, if anything the incentives lie with underestimating—not overestimating—losses. These plant closures brought slaughter capacity more in line with cattle supplies, allowing the remaining packing facilities to run more efficiently.

The above quotations from U.S. beef packing firms reveal that both closures were executed with company-wide capacity utilization and profits in mind. In particular, Cargill’s mention of capacity utilization concerns at “other beef plants” reveals an increased use of multi-plant coordination in the beef packing sector. In this study, multi-plant coordination is defined as the firm-level coordination of procurement and slaughter activities across plants by multi-plant beef packers with the goal of maximizing corporate-level—as opposed to plant-level—profits.² Economists may wonder why, if multi-plant coordination is optimal behavior from a profit-maximization perspective, firms have not always performed multi-plant coordination. Available empirical evidence suggests, however, that as recently as 2005, beef packing companies did not appear to be coordinatting fed cattle procurement and slaughter activities across plants in any meaningful way (Koontz and Lawrence, 2010). Hence, the question is not if or even when beef packers shifted to completely implementing multi-plant coordination—their own statements confirm they use the practice, and the transition must have began sometime after 2005. Instead, the relevant question to ask is, what are the implications of this business practice for the different segments of the beef supply chain?

Critically, as will be demonstrated, the beef packing industry’s move to multi-plant coordination helps explain recently-observed price dynamics. Namely, U.S. Department of Agriculture (USDA) Economic Research Service beef price spread data indicates that from January 2010 until August 2015, when Tyson closed its Denison plant, aggregate farm-to-wholesale beef price spreads averaged $34/cwt, with the farmer share averaging

²This is similar to the definition implicitly used by Koontz and Lawrence (2010). It is also similar to the definition used by Chen (2002) in a study of the U.S. petroleum refining industry, but differs slightly from the definition provided by Bhatnagar, Chandra, and Goyal (1993), who emphasize operation of multiple plants that are vertically integrated.
From September 2015 to November 2021, the farm-to-wholesale price spread averaged $87/cwt, with the average farmer share over that period declining to 42%. Price spreads in 2021 have been especially high, averaging $161/cwt from January through November, with the corresponding average farmer share representing only 37%. While initially temporarily widening following the August 2019 fire at the Tyson packing plant near Holcomb, Kansas, and again in 2020 due to packing plant disruptions in the wake of COVID-19 (USDA-AMS, 2020a; Lusk, Tonsor, and Schulz, 2021), historically wide farm-to-wholesale beef price spreads have persisted into 2021 without any analogous exogenous market shock.

While multi-plant coordination alone does not explain these persistently wide price spreads, the business practice is right at the intersection of a host of hot-button features of the U.S. beef supply chain, including concentration, geography and transportation costs, alternative marketing arrangements (AMAs), and cattle cycles and packing capacity. There is no shortage of academic literature pertaining to these cattle industry characteristics, but none of these features alone has been demonstrated to solely cause such price spread behavior. Accordingly, this study proposes that it is multi-plant coordination in conjunction with these salient features that is the cause of observed trends in beef price spreads. Given packing plants were optimizing somewhat independently before 2005, and then the largest processors subsequently began coordinating procurement and slaughter activities across plants, it is as if more than 20 separate economic agents suddenly consolidated into four. While not necessarily the motivation for packers employing multi-plant coordination, this undoubtedly has implications for beef price spreads and the competitiveness of fed cattle pricing in aggregate. Hence, this business practice must be taken into careful consideration as producers, beef packers,

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3The USDA Economic Research Service farm-wholesale-retail meat price spread series is widely used for informing producers, retailers, food service, consumers, analysts, consultants, investors, academics, government agencies, market regulators, and policymakers about livestock and meat price relationships (Schroeder et al., 2019). Schroeder et al. (2019) and Lusk, Tonsor, and Schulz (2021) provide definitions, measurement details, and interpretation of price spread data. Recent data is available online at https://www.ers.usda.gov/data-products/meat-price-spreads/meat-price-spreads/, with historical data being compiled and made available by the Livestock Marketing Information Center.
government entities, and other stakeholders consider consequential actions for the industry and its future.

This study proceeds as follows. Section 2 discusses key features of the U.S. beef supply chain, and section 3 provides a review of relevant literature. In section 4, we develop theoretical models from a Salop Circular City framework modified to feature cattle producers who supply fed cattle to beef packing plants that operate with increasing marginal costs. The baseline model in section 4.1 considers processing plants that maximize profits at the plant level, with the key insight from the baseline model being that prices offered to cattle producers are a function of the downstream (boxed) beef price. In section 4.2, we present a multi-plant coordination model, which is the same as the baseline model except that beef packer profit maximization occurs at the firm level as opposed to the individual packing plant level. The primary result from the model is that multi-plant coordination can result in fed cattle prices that are not necessarily a function of downstream beef prices for individual packers.

The discussion in section 5 applies the models developed in section 4 to describe recent events in the beef packing sector. Namely, section 5.1 models when multi-plant coordinating beef packers like Cargill or Tyson might find it optimal to permanently shutdown a plant, as they have historically done. Section 5.2 presents a follow-up scenario, which demonstrates that a new beef packing plant opened by a different firm can reintroduce correlation between the downstream beef price and fed cattle prices. Finally, section 6 concludes and discusses avenues for future research.

2. Industry Background

A far cry from the cowboys and cattle drives enshrined in Americana, the U.S. beef supply chain has evolved over time. Today, the U.S. cattle and beef industries consistently provide consumers, domestic and abroad, with dependable volumes of high quality beef products at competitive prices. In 2020, the United States ranked first internationally in beef and veal production with nearly 12.4 million metric tons produced (USDA-FAS, 2021). The United States also ranked first internationally in domestic beef and veal consumption in
2020 with more than 12.5 million metric tons consumed (USDA-FAS, 2021). In 2020 alone, U.S. cattle marketed for slaughter generated $63.1 billion of receipts and resulted in $123.3 billion (retail equivalent value) of beef produced (USDA-ERS, 2021). The industry changes that have taken place to support such levels of production, processing, trade, and end-user consumption, however, have not come without controversy.

Beef packing consolidation occurred rapidly in recent decades. The beef packing industry had a four-firm concentration ratio of only 36% in 1980 (USDA-GIPSA, 2006). However, by 1995, four-firm concentration for beef packers exceeded 80% and has remained near or above that level ever since (USDA-GIPSA, 2006; USDA-AMS, 2020). Consider Figure 1, which depicts U.S. beef packing plants with more than 500-head-per-day of fed cattle slaughter capacity. In Figure 1, dot size indicates slaughter capacity while dot color indicates firm ownership. As can be seen, the largest plants are owned by the four largest firms, and each of the four largest firms operates more than one large plant.

![Figure 1: Fed cattle packing plants by daily capacity (size) and firm (color) (Map created using Tableau Desktop and author's calculations from a compilation of industry data)](image)

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As made evident in Figure 1, most producers would find it difficult to sell large volumes of cattle to a packing firm that does not also operate a plant in at least one other region. While this arrangement is more likely when there is concentration of some degree, concentration is not a sufficient or even necessary condition. One can imagine a world in which a few firms dominate the national market but single firms predominantly operate in separate regions. One can also imagine the case where a few firms dominate the entire market but single firms operate only a single immensely large plant in their respective region(s). These hypothetical market arrangements having not arisen over time suggests there must be some economic explanation for the currently observed structure.

3. Literature Review
Operating multiple plants in different geographic regions has long been recognized as a potential source for economic advantages in a variety of industries (Scherer et al., 1975). That said, there has not been much work regarding the economics of operating multiple plants in the beef packing industry specifically, with advantages typically being assumed (Ward, 2010). One theorized advantage is that beef packing firms with multiple plants can avoid diseconomies of scale due to transportation costs (MacDonald, 2003). Another theorized advantage is the opportunity for multi-plant firms to optimize capacity utilization across plants. As described by MacDonald (2003), packers “that own multiple plants can direct livestock flows among them in such a way as to keep plant labor and capital fully employed at a planned level of hours of use” (p. 431). This multi-plant coordination of slaughter volumes allows for firm-level profit maximization—beef packers can maximize profits by optimally allocating cattle among packing plants in order to supply optimal levels of beef to consumers while making best use of in-plant processing cost functions. Operating in such a way has benefits for beef packers, especially since when “…one plant is closed for food safety reasons, other plants can continue operating, both purchasing cattle and supplying beef and by-products to customers” (Ward, no date, p. 2). The high-profile packing plant closures in 2019 and 2020 were not related to food safety, but the intuition holds nonetheless. Anecdotally, this reallocation occurred after the
closure of the Tyson plant in Holcomb, Kansas, following the August 2019 fire, when “Tyson appears to have shipped a significant portion of the cattle it would have previously processed at the Holcomb plant to its other plants” (USDA-AMS, 2020a, p. 4). Finally, moving toward multi-plant coordination of activities could allow for smaller packer procurement staffs if procurement activities are conducted at the firm level rather than the plant level. Procurement staff represent significant costs to individual plants, and while often attributed to the development and use of AMAs, packers have cut procurement staffs by one-half to two-thirds in recent years (Koontz, 2015).

MacDonald (2003) makes the qualitative statement that not all packers “operate their plants as integrated systems” (p. 431), but only one previous empirical study—Koontz and Lawrence (2010)—describes an empirical evaluation of multi-plant optimization in beef packing. Using plant-level profit and loss (i.e., accounting) data for the four largest beef packers in the United States, Koontz and Lawrence (2010) measure the effects of AMAs on packer profits, gross margins, and costs. In the course of doing so, they demonstrate that plant-level average total cost curves are declining, nearly linear, and notably steep. Most relevant for our study is their assertion that for the October 2002 through March 2005 period, “Very few firms appear to conduct any degree of multiplant [sic] coordination. For the firms that did, volumes appeared to be reduced most frequently at one or two specific small plants” (Koontz and Lawrence, 2010, p. 21). In particular, they point out that monthly plant slaughter volumes are highly positively correlated across plants within multi-plant firms both in levels and in first differences. Many of the plants operated at low capacity levels and experienced losses during this time period, leading them to claim that the data suggests individual plants “operated as separate profit centers” (Koontz and Lawrence, 2010, p. 21). Koontz and Lawrence (2010) do admit that, from their analysis, it is difficult to make strong claims regarding multi-plant coordination since transportation costs were not considered. Despite that, the only empirical evidence available regarding multi-plant coordination indicates that as of 2005, it “was simply not strong” (Koontz and Lawrence, 2010, p. 21). This stands in stark contrast to the multi-plant coordination that
major packers have since embraced today for decisions regarding even the largest of plants.

Many studies of the beef supply chain focus on features of the fed cattle market that are theoretically distinct from, but related to, multi-plant coordination. Here we discuss literature examining four of the more salient topics and their connection with the present study.

**Market Concentration.** Given the high degree of concentration in beef packing, it should not come as a surprise that “the U.S. beef-packing sector has been the subject of more empirical studies of market power than any other industry in the world” (Sexton, 2000, p. 1092). Nevertheless, nearly every study arrives at more-or-less the same conclusion as Schroeter’s (1988) seminal work on the topic—beef packing companies exert little monopsony power in the fed cattle market and little monopoly power in the beef market. Put succinctly in a recent review by Wohlgenant (2013), “Despite the preponderance of evidence that producers are not worse off from increased concentration in livestock industries, there still remain much skepticism and allegations that anticompetitiveness by meatpackers influences prices and returns of producers” (p. 2). The ubiquitous nature of this result could in part be semantics—“not worse off” is a low bar to clear that is difficult to refute and does little to address concerns regarding the “fairness” of welfare distribution along the supply chain. Still, the near consensus in opinions among economists past and present is noteworthy. Germane to the present study is that, though concentration and multi-plant coordination are not necessarily related other than tautologically, they are still related (Scherer et al., 1975). Simply put, multi-plant coordination is highly unlikely in an industry with low concentration.

**Geography and Transportation Costs.** Many studies of the fed cattle industry recognize the nearly definitional nature of geography, and consequentially transportation costs, in fed cattle production. Several studies evaluate market integration in U.S. cattle feeding regions, both before the implementation of Livestock Mandatory Reporting (LMR) (Goodwin and Schroeder, 1991) and after (Pendell and Schroeder, 2006). Generally speaking, these studies suggest regional markets have become more integrated over time,
particularly after LMR was enacted. More recently, the literature attempts to account for region-specific geography effects. Crespi and Sexton (2005) find that fed cattle prices in the Texas Panhandle region were $5\% - 10\%$ below prices in a competitive setting. They attribute these lower prices in large part to transportation costs that make shipping cattle to other regions prohibitive. Pudenz and Schulz (2021) show that basis for fed dairy cattle widened by as much as $15$/cwt (depending on the transaction type) in the Iowa-Minnesota reporting region following the decision by Tyson to stop procuring fed dairy cattle for its processing plant in Joslin, Illinois, in late 2016. McKendree, Saitone, and Schaefer (2021) demonstrate the national implications of this single plant’s change in procurement practices, finding that national fed Holstein prices decreased $5.5\%$ for live cattle and $3.5\%$ for dressed cattle as a result of Tyson’s decision. The fact that procurement practice changes at a single plant could have such a large price impact highlights a broader point made by Crespi, Saitone, and Sexton (2012), which is the “ever-increasing importance of shipping costs in defining regional procurement markets” (p. 678). In fact, survey data suggests that fed cattle are travelling further to slaughter facilities than they have in the past. In 2011, cattle from U.S. feedlots with more than 1,000 head traveled an average of 166 miles (USDA-APHIS-VS, 2013). This is an increase from 1999, during which comparable surveys indicated that feedlots with more than 1,000 head travelled an average of 132 miles to slaughter (USDA-APHIS-VS, 2000). As a whole, these studies definitely show that geographical and transportation considerations matter greatly for the fed cattle industry and even relate to lower prices for fed cattle producers. That said, none of these studies show that geography by itself has enough of an impact to explain current price spread behavior.

**Alternative Marketing Arrangements (AMAs).** The impacts of cattle procured through AMAs—formerly called captive supplies—have also been frequently studied. Two early studies of AMAs in cattle markets are Hayenga and O’Brien (1991) and Elam (1992). While the former provides mixed results regarding the impact of forward contract deliveries in

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*Conversations with individuals familiar with the industry lead the authors to believe these distances today are even higher than they were in 2011, suggesting transportation costs could have an even greater impact.*
other states on Colorado cattle market prices, the latter uses correlation coefficients and price transmission equations to show that contracting volume has a negative impact on cash prices. Xia and Sexton (2004) present a theoretical model that demonstrates how, in certain situations, use of a specific type of AMA can lead to lower spot market prices. Even so, AMAs continue to increase in prevalence and prominence, with only roughly 20% of national trade occurring in the negotiated (i.e., spot) market in any particular week. These AMAs are a cost-reducing innovation that provide benefits to beef packers and the cattle producers who adopt them. Specifically, AMAs aid in supply chain management and reduce risks and costs of participating in the cash market, though only for those that use them (Koontz, 2015). Federal legislation addressing low spot market volumes by forcing a certain percentage of transactions (e.g., 50%) has been discussed for nearly 20 years (Grassley, 2021), but some prominent economists argue that such policies are welfare reducing for cattle producers as a whole (Koontz, 2021). Hence, the literature does not support the notion that AMAs by themselves are responsible for observed farm-to-wholesale price spread dynamics, though the supply chain management benefits of AMAs may allow for effective multi-plant coordination.

**Cattle Cycles and Packer Capacity.** Cattle cycles have long been recognized as a prominent feature of the cattle industry (Rosen, Murphy, and Scheinkman, 1994). Packer capacity is not unlimited, so as cattle supplies vary throughout the cattle cycle, so do packer procurement decisions (McKendree, Saitone, and Schaefer, 2021; Pudenz and Schulz, 2021). Separate research demonstrates that higher cattle inventories can lead to lower fed cattle prices, and that increased beef packer market power in cattle procurement amplifies this effect (Crespi, Xia, and Jones, 2010). The current cattle inventory cycle began in 2014 and is just past its peak. Many economists view persistently wide beef price spreads as being primarily a result of cattle supplies being out of step with slaughter capacity, and that the spread will narrow as cattle supplies contract and slaughter capacity increases in coming years. For instance, in Congressional testimony in

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5Current and historical data is available in the National Weekly Fed Cattle Comprehensive reports at https://usda.library.cornell.edu/concern/publications/c534g2593?locale=es.
July 2021, Agricultural Economist Jayson Lusk of Purdue University asserted:

Cattle inventory is falling. Feed prices are rising. There is a drought in [sic] West. These factors will, over time, likely bring cattle numbers closer in line with current capacity. Moreover, even absent federal investments, there are a number of private initiatives to increase automation and add more packing capacity. More capacity, and fewer cattle, will help support future cattle prices (Lusk, 2021, p. 2).

This explanation is sound, but less than complete. High cattle supplies at the peaks of cattle inventory cycles are not a new phenomenon. In fact, two cattle cycles have had peaks since beef packer concentration more or less leveled out in 1995 (i.e., 1996 and 2007), but in neither case were such record price spreads observed. Exogenous market shocks like the 2019 Holcomb fire and the 2020 COVID-19 shutdowns certainly did not work to narrow the price spread, but something must have changed since the last cattle cycle peak in 2007 to cause such extraordinary packer margins to persist into 2021 without any obvious precipitating market shock.

These four concepts are separate, but they often overlap and hence are often discussed together. What has not yet been discussed in the literature, however, is how multi-plant coordination is directly related to all of them. Koontz and Lawrence (2010) get the closest to doing so, but the authors themselves admit that, from their analysis, it is difficult to make strong claims regarding multi-plant coordination since transportation costs were not considered.

Theoretical studies are not uncommon in the robust literature focusing on the U.S. beef supply chain. These studies typically are of the “applied theory” variety, and they often focus on producing a so-called “possibility result” to a non-obvious research question. In many cases, empirical evaluations of these research questions are difficult because of the lack of publicly available data. For instance, Xia and Sexton (2004) use a two-period model to demonstrate that a specific kind of AMA in the first period can lead to depressed spot market prices in the second period. This particular study created its own sub-literature of sorts, with Zhang and Brorsen (2010) and Xia, Crespi, and Dhuyvetter (2019) developing the model further. Other theoretical studies abound, and our study follows a similar path.
4. Theoretical Models

For readers familiar with the industrial organization literature, we adapt our theoretical models from the standard Salop Circular City framework (Belleflamme and Peitz, 2015). We make three primary modifications to adapt the Salop framework to the subject at hand. First, while location in the Salop framework typically represents location in quality or characteristic space, location in our models represents location in geographic space. Second, a situation with many buyers and few sellers usually motivates the Salop framework, while here there are many sellers and few buyers. This is similar to the adaptation Zhang and Sexton (2001) made to the Hotelling Linear City model, but the Salop model is more appropriate for modeling entry and exit. Third, the Salop framework typically features firms with constant marginal costs. In these models, each plant has increasing in-plant marginal costs, reflecting in-plant capacity constraints (Ma and Lusk, 2021).

4.1. Baseline Model

Let $N$ beef packing plants owned by packing company $A$ be distributed equidistantly on a circle with circumference equal to 1. Let these packing plants be indexed by $n = 1, \ldots, i - 1, i, i + 1, \ldots, N$. The beef packing plants offer the same plant-gate price for fed cattle (input) to all producers, and they convert the fed cattle into boxed beef (output) according to a fixed proportions technology (Zhang and Sexton, 2001; Xia and Sexton, 2004).

Let mass $M$ of cattle producers be uniformly distributed on the circle. These producers are identical aside from location on the circle, which represents geographical location and is denoted by index $m \in [0, 1]$. Each of the $M$ producers supplies one unit of fed cattle inelastically as long as the price the producer receives is greater than their reservation price $f$. For producers supplying cattle to plant $i$, this price equals the plant-gate price $r_i$ less transportation costs, which are a linear function of the distance from plant $i$ to producer $m$’s position on the circle. Assume that transportation costs are entirely passed through to

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Fed cattle are marketed in various ways, including according to animal sex (i.e., steers, heifers, mixed), selling basis (i.e., live FOB, live delivered, dressed FOB, dressed delivered), and transaction type (i.e., negotiated, formula, forward contract, negotiated grid). This model assumes a single plant-gate cattle price in
the producer (Koontz and Lawrence, 2010). Hence, producer $m$ faces the following decision problem:

$$\max_{n=i,i+1} \{ r_n - \tau |l_n - m| - f \} \quad (1)$$

where plants $n = i$ and $i + 1$ are the plants on either side of cattle producer $m$, with plant $n$’s location being $l_n = n/N$. Let producer $m_{i,i+1}$ be the cattle producer who is indifferent between supplying their cattle to packing plants $i$ and $i + 1$. This indifferent producer is defined by:

$$r_i - \tau \left( m_{i,i+1} - \frac{i}{N} \right) - f = r_{i+1} - \tau \left( \frac{i+1}{N} - m_{i,i+1} \right) - f \quad (2)$$

This expression can be solved for $m_{i,i+1}$:

$$m_{i,i+1} = \frac{r_i - r_{i+1}}{2\tau} + \frac{2i+1}{2N} \quad (3)$$

Substituting $i - 1$ for $i$, producer $m_{i-1,i}$ is the cattle producer who is indifferent between supplying their cattle to packing plant $i - 1$ and $i$. This producer is defined as:

$$m_{i-1,i} = \frac{r_{i-1} - r_i}{2\tau} + \frac{2i-1}{2N} \quad (4)$$

Assuming in equilibrium that $r_i$ is sufficiently high relative to reservation price $f$ (i.e., the market is “covered”), plant $i$ attracts all fed cattle located between indifferent producers $m_{i-1,i}$ and $m_{i,i+1}$. Given there is mass $M$ of producers, this means that the quantity supplied to plant $i$ is:

$$q_i (r_{i-1}, r_i, r_{i+1}) = (m_{i,i+1} - m_{i-1,i}) \ast M = \left( \frac{2r_i - r_{i-1} - r_{i+1}}{2\tau} + \frac{1}{N} \right) \ast M \quad (5)$$

Let all plants $n = 1, ..., N$ owned by firm $A$ have the same in-plant cost structure $c(q_n)$, with $c'(q_n) > 0$ and $c''(q_n) > 0$. In the baseline model, assume that, as asserted by Koontz and Lawrence (2010) regarding the 2002–2005 time period, regional packing plants are not equilibrium, which is reasonable in light of optimizing behavior in response to arbitrage opportunities across cattle marketing methods.
employing multi-plant coordination. Clearly, the degree of implementation of multi-plant coordination falls on a spectrum, but to illustrate the point most clearly, we assume the extreme case here that individual plants are “operated as separate profit centers” (Koontz and Lawrence, 2010, p. 21). Without loss of generality, let plant $i$ maximize profits in the cattle market while taking producer supply $q_i$ into account:

$$\max_{r_i} \Pi (r_i) = (p - r_i) * q_i - c(q_i)$$

subject to $q_i (r_{i-1}, r_i, r_{i+1}) = \left( \frac{2r_i - r_{i-1} - r_{i+1}}{2\tau} + \frac{1}{N} \right) * M$

Plugging the constraint into the maximization problem, we see that we have:

$$\max_{r_i} \Pi (r_i) = (p - r_i) \left( \frac{2r_i - r_{i-1} - r_{i+1}}{2\tau} + \frac{1}{N} \right) M - c\left( \frac{2r_i - r_{i-1} - r_{i+1}}{2\tau} + \frac{1}{N} \right) M$$

(7)

Taking the first order condition with respect to $r_i$, and equating it with zero, we have:

$$\frac{pM}{\tau} - 2r_i \frac{M}{\tau} + r_{i-1} \frac{M}{2\tau} + r_{i+1} \frac{M}{2\tau} - \frac{M}{N} - \frac{\partial c}{\partial q_i} \frac{\partial q_i}{\partial r_i} = 0$$

(8)

Recognizing that $\frac{\partial q_i}{\partial r_i} = \frac{M}{\tau}$, we simplify to obtain:

$$p - 2r_i + \frac{r_{i-1}}{2} + \frac{r_{i+1}}{2} - \frac{\tau}{N} - \frac{\partial c}{\partial q_i} = 0$$

(9)

By analogy, it is possible to find $N$ such equations, one for each plant $n$. These $N$ equations implicitly define packer $A$’s optimal prices $r_n^*$ for $i = 1, ..., N$. Recalling that plants are distributed equidistantly, and that plants have identical cost structures, the focus here is on the symmetric equilibrium in which the plants, though operating as their own profit centers, each find it optimal to offer the same price for fed cattle. Setting $r_n = r$ for $n = 1, ..., N$, we first note that the optimal supply function simplifies to no longer be a function of fed cattle prices:

$$q^* = \frac{M}{N}$$

(10)
This means that all plants slaughter an equal quantity of cattle in equilibrium, which in turn means that \( \frac{\partial c}{\partial q_n} \) is equal for \( n = 1, ..., N \). Hence, we can easily solve for the following expression for symmetric equilibrium price \( r^* \):

\[
r^* = p - \frac{\tau N}{\partial q} - \frac{\partial c}{\partial q}
\]

This price has a straightforward interpretation—the plant-gate fed cattle price offered by beef packer \( A \)'s plants is the downstream beef price less the so-called packer margin, which in this case is a combination of costs related to transportation and in-plant processing costs. Critical to this study is that optimal price \( r^* \) is a function of downstream beef price \( p \). This means that when plants are operating independently, the "competition" among the plants owned by packer \( A \) to procure cattle introduces competitive forces that cause fed cattle prices to move in lockstep with downstream beef prices.

4.2. Multi-plant Coordination Model

In section 4.1, we develop a baseline model in which, as Koontz and Lawrence (2010) suggest, packing plants that are owned by the same firm operate as independent profit centers. In this section, we develop a counterfactual model that incorporates multi-plant coordination of procurement and slaughter activities to maximize packing firm profits.

Suppose now that packing firm \( A \), with its plants already located as they were in the baseline model, decides to implement multi-plant coordination. The fed cattle producer problem remains the same, but now we consider the other extreme case for the packer in which the packing firm is maximizing profits at the firm—rather than the plant—level. Consider firm \( A \)'s maximization problem:

\[
\max_{\{r_n\}_{n=1}^N} \sum_{n=1}^N \Pi (r_n) \equiv \sum_{n=1}^N [(p - r_n) * q_n - c (q_n)]
\]

subject to

\[
q_n (r_{n-1}, r_n, r_{n+1}) = \left( \frac{2r_n - r_{n-1} - r_{n+1}}{2\tau} + \frac{1}{N} \right) * M \text{ for } n = 1, ..., N
\]

\[
\frac{r_i}{2} + \frac{r_{i+1}}{2} - \frac{\tau}{2 * N} \geq f
\]
and $\frac{r_{i-1}}{2} + \frac{r_i}{2} - \frac{\tau}{2* N} \geq f$

Several features of this maximization problem are worth discussing. First, since the previously built plants are equidistant and have identical in-plant cost structures, it follows to once again focus on the solution where prices are equal across all plants. Let this multi-plant coordination price be $r_c$. Second, maintaining the assumption that the entire market is covered, there are two additional constraints regarding the fed cattle price relative to the reservation price. Specifically, the constraints dictate that the plant-gate price less transportation costs (i.e., the net price) for the indifferent producer must not fall below the indifferent producer’s reservation price. Without loss of generality, the constraints for plant $i$ are derived as follows:

$$r_i - \tau (m_{i,i+1} - l_i) \geq f \iff \frac{r_i}{2} + \frac{r_{i+1}}{2} - \frac{\tau}{2* N} \geq f \quad (13)$$

$$r_i - \tau (l_i - m_{i-1,i}) \geq f \iff \frac{r_{i-1}}{2} + \frac{r_i}{2} - \frac{\tau}{2* N} \geq f \quad (14)$$

Notice that the two constraints—one for cattle supplied from producers on either side of plant $i$—are mathematically redundant when all fed cattle prices are set to equal $r_c$. These constraints remained implicit in the previous maximization problem, but we will show that they must be made explicit in the case of multi-plant coordination.

Substituting $r_c$ into the maximization problem where appropriate, and simplifying, we are left with:

$$\max_{r_c} \Pi (r_c) = (p - r_c) * M - c (q_n) * N \quad (15)$$

subject to $q_n = \frac{M}{N}$ for $n = 1, ..., N$

and $r_c - \frac{\tau}{2* N} \geq f$

The Lagrangian equation for this packer profit maximization problem is as follows:

$$\mathcal{L} (r_c) = (p - r_c) * M - c \left( \frac{M}{N} \right) * N + \lambda \left( r_c - \frac{\tau}{2* N} - f \right) \quad (16)$$
The first order necessary conditions for \( r^c \) and \( \lambda \), respectively, are as follows:

\[-M + \lambda \leq 0, \quad r^c \geq 0, \quad r^c \frac{\partial L (r^c)}{\partial r^c} = 0\]

\[r^c - \frac{\tau}{2 * N} \geq f, \quad \lambda \geq 0, \quad \lambda \frac{\partial L (r^c)}{\partial \lambda} = 0\]

By process of elimination, we can show that the constraint must bind for there to be a non-zero solution for \( r^c \). Put differently, it is optimal for the packing firm to set fed cattle prices as low as possible. Thus, without modeling the constraint explicitly, no non-zero solution for \( r^c \) can be found. This is because, as demonstrated by the packer objective function, profits are decreasing in \( r^c \). The lowest possible fed cattle price is when the net price received by the indifferent producer is exactly equal to the reservation price, which results in the following solution for optimal plant-gate price:

\[r^c* = f + \frac{\tau}{2 * N}\]  

(17)

Critically, the optimal multi-plant coordinating packer fed cattle price \( r^c* \) is NOT a function of downstream beef price \( p \). Instead, the plant-gate price is “anchored” to the cattle producers’ reservation price \( f \). Hence, by moving to multi-plant coordination, the beef packer is able to internally unhinge fed cattle prices from downstream beef prices. This does not necessarily mean that fed cattle prices are lower—that depends on the relative levels of \( p \) and \( f \) and the values of other parameters. It does, however, eliminate any correlation between downstream beef prices and upstream fed cattle prices arising from intra-firm competition. Any correlation would have to arise from competition between beef packer \( A \) and other beef packers in the market.

5. Discussion

It has been shown that, in equilibrium, a beef packer employing multi-plant coordination can internally eliminate dependence between downstream beef prices and upstream fed cattle prices. Pushing the modeling framework a bit further, what can be said about why a
multi-plant coordinator would permanently shut down a plant as Tyson and Cargill did during the previous decade? What are the short-run effects of such a shutdown? Furthermore, following such a shutdown, what would be the impact of a new plant with different ownership entering the market?

5.1. Optimal Plant Closure

Suppose that, due to changing market conditions, beef packer \( A \) is considering closing one of its \( N \) packing plants (i.e., plant \( i \)). Importantly, the remaining \( N - 1 \) plants owned by packer \( A \) cannot be moved. Due to the inelastic supply of cattle in the short-run due to the cattle inventory cycle, this means that the cattle previously slaughtered at plant \( i \) must be slaughtered at another one of its plants.

\[
r_1 - \tau (m_{1,3} - l_1) - f = r_3 - \tau (l_3 - m_{1,3}) - f
\]

Figure 2: Beef packing plant location for firm \( A \) and indifferent producers pre- and post closure of plant 2

For concreteness, suppose the beef packer operates three total plants and without loss of generality is considering closing plant 2 (as shown in Figure 2). As demonstrated in Figure 2, to proceed we must find new expressions for quantity supplied to the remaining two plants, which depend on a new expression for the indifferent producer \( m_{1,3} \):

\[
r_1 - \tau (m_{1,3} - l_1) - f = r_3 - \tau (l_3 - m_{1,3}) - f
\]
Plugging in expressions for \( l_n = \frac{n}{3} \), it is easy to solve for \( m_{1,3} \):

\[
m_{1,3} = \frac{r_1 - r_3}{2\tau} + \frac{2}{3}
\]  

(19)

In order to calculate quantity supplied, we must also find an expression for indifferent producer \( m_{3,1} \):

\[
r_3 - \tau (m_{3,1} - l_3) - f = r_1 - \tau (l_1 - m_{3,1}) - f
\]  

(20)

In the context of the Salop framework, location \( l_3 = \frac{3}{3} \) is equivalent to location \( l_0 = \frac{0}{3} \) on a unit circle, and \( l_1 = \frac{1}{3} \) is equivalent to \( l_4 = \frac{4}{3} \). Using these equivalencies, it is convenient to find two equivalent expressions for location \( m_{3,1} \) as follows:

\[
r_3 - \tau \left( m_{3,1} - \frac{0}{3} \right) - f = r_1 - \tau \left( \frac{1}{3} - m_{3,1} \right) - f \iff m_{3,1} = \frac{r_3 - r_1}{2\tau} + \frac{1}{6}
\]  

(21)

\[
r_3 - \tau \left( m_{3,1} - \frac{3}{3} \right) - f = r_1 - \tau \left( \frac{4}{3} - m_{3,1} \right) - f \iff m_{3,1} = \frac{r_3 - r_1}{2\tau} + \frac{7}{6}
\]  

(22)

Using the first expression for \( m_{3,1} \), the quantity of cattle supplied to plant 1 is as follows:

\[
q_1 (r_1, r_3) = (m_{1,3} - m_{3,1}) \times M = \left( \frac{r_1 - r_3}{\tau} + \frac{1}{2} \right) \times M
\]  

(23)

Now, using the second expression for \( m_{3,1} \), the quantity of cattle supplied to plant 3 can be derived:

\[
q_3 (r_1, r_3) = (m_{3,1} - m_{1,3}) \times M = \left( \frac{r_3 - r_1}{\tau} + \frac{1}{2} \right) \times M
\]  

(24)

These expressions can be used in the following maximization problem:

\[
\max_{r_1, r_3} \Pi (r_1, r_3) = (p - r_1) \times q_1 - c(q_1) + (p - r_3) \times q_3 - c(q_3)
\]  

(25)

subject to \( q_1 = \left( \frac{r_1 - r_3}{\tau} + \frac{1}{2} \right) \times M \)

\[
q_3 = \left( \frac{r_3 - r_1}{\tau} + \frac{1}{2} \right) \times M
\]
and \( \frac{r_1}{2} + \frac{r_3}{2} - \frac{\tau}{3} \geq f \)

Plants are no longer equidistant as they were before. That said, given there are only two plants with identical in-plant cost structures, it still follows to focus on the solution where prices are equal across both plants. Let this multi-plant coordination price after a shutdown be \( r^s \). When prices are set to be equal across plants, the producer supply functions simplify to \( \frac{M}{2} \) and are equal across plants. Our constraint related to the reservation price is now different, however. The constraints for plant 1 are derived as follows:

\[
 r_1 - \tau (m_{1,3} - l_1) \geq f \iff \frac{r_1}{2} + \frac{r_3}{2} - \frac{\tau}{3} \geq f \tag{26}
\]

\[
 r_1 - \tau (l_1 - m_{3,1}) \geq f \iff \frac{r_3}{2} + \frac{r_1}{2} - \frac{\tau}{6} \geq f \tag{27}
\]

Analogue constraints can be derived for plant 3. Notice that constraint (26) holding is sufficient for constraint (27) holding. Proceeding with only constraint (26), and substituting fed cattle price \( r^s \) where necessary, the maximization problem is as follows:

\[
 \max_{r^s} \Pi(r^s) = (p - r^s) * M - c \left( \frac{M}{2} \right) * 2 \tag{28}
\]

subject to \( r^s - \frac{\tau}{3} \geq f \)

At this point, it is easy to see that the maximization problem is very similar to the more general problem in section 4.2, except for the updated constraint. The Lagrangian formulation for this maximization problem is as follows:

\[
 \mathcal{L}(r^s) = (p - r^s) * M - c \left( \frac{M}{2} \right) * 2 + \lambda \left( r^s - \frac{\tau}{3} - f \right) \tag{29}
\]

Taking the first order conditions for \( r^s \) and \( \lambda \), respectively:

\[-M + \lambda \leq 0, \quad r^s \geq 0, \quad r^s * \frac{\partial \mathcal{L}(r^s)}{\partial r^s} = 0 \]
\[ r^s - \frac{\tau}{3} \geq f, \lambda \geq 0, \lambda \frac{\partial L(r^s)}{\partial \lambda} = 0 \]

As was the case previously, by process of elimination, we can show that the constraint binds. This, in turn, means that the new fed cattle price is simply:

\[ r^{**} = f + \frac{\tau}{3} \]  \hspace{1cm} (30)

For comparison, note that this is a higher plant-gate price than before a shutdown (i.e., when \(N = 3\), equation (17) gives us \(r^{cx} = f + \frac{\tau}{2}\)). This has several implications. From the beef packer’s perspective, since the beef packer pays the plant-gate price for all of the cattle, the beef packer must pay \(\frac{\tau}{6} \cdot M\) more in total to procure cattle. All cattle previously going to plants 1 and 3 receive higher net prices than before the closure of plant 2. However, only half of the cattle previously slaughtered by plant 2 are now receiving higher net prices once transportation costs are taken into account. The other half of the cattle previously slaughtered by plant 2 are now receiving lower net prices. Overall, this results in average price received by producers being slightly higher than previously. This theoretical result is consistent with the typical finding of many beef packing industry studies (Wohlgenant, 2013). Given multi-plant coordination, on average producers are “no worse off” when there is one fewer plant, in part due to efficiency gains that are passed on to (some) producers. This is little consolation, however, to the fed cattle producers located most closely to plant 2. Furthermore, one must not forget that when a packer is using multi-plant coordination, it already has internally reduced correlation between downstream beef prices and upstream fed cattle prices.

If the average fed cattle prices are slightly higher than previously due to higher transportation costs, then beef packer \(A\) would only choose to shut down plant 2 if there were production cost gains from doing so. Letting \(\gamma\) be the fixed cost of operating a single plant, total profit pre- and post-shutdown can be used to derive the following shutdown
condition:
\[ M (p - r^{ss}) - 2c \left( \frac{M}{2} \right) - 2\gamma > M (p - r^{cs}) - 3c \left( \frac{M}{3} \right) - 3\gamma \]
\[ \iff -M \left( \frac{\tau}{6} \right) > 2c \left( \frac{M}{2} \right) - 3c \left( \frac{M}{3} \right) - \gamma \] (31)

Hence, we have derived a shutdown decision in terms of overall cattle supply \( M \), transportation costs \( \tau \), and cost function parameters. Intuitively, the left-hand side of inequality (31) is the lost revenue due to having to pay higher net prices to attract cattle that are farther away, while the right hand side is the change in costs from running fewer plants at higher capacity. If revenue changes are less negative than the change in costs, the plant will be shut down. Here, the exact functional form and parameters of the in-plant processing function matter a great deal, as does fixed cost \( \gamma \).

Several additional observations are worth noting. First, the left-hand side of shutdown condition (31) is decreasing in \( \tau \) while the right hand side does not vary in \( \tau \). This means that a shutdown is less likely to occur as transportation costs increase. Second the left-hand side is decreasing in cattle supply \( M \) while the right hand side is increasing in \( M \):

\[
2 \frac{\partial c}{\partial q^{ss}} \frac{\partial q^{ss}}{\partial M} - 3 \frac{\partial c}{\partial q^{cs}} \frac{\partial q^{cs}}{\partial M} = 2 \frac{\partial c}{\partial q^{ss}} \frac{1}{2} - 3 \frac{\partial c}{\partial q^{cs}} \frac{1}{3} = \frac{\partial c}{\partial q^{ss}} - \frac{\partial c}{\partial q^{cs}} > 0
\] (32)

since \( q^{ss} > q^{cs} \) and in-plant marginal costs are increasing. This means that shutdown is less likely to occur for higher \( M \) or conversely, that shutdown is more likely to occur for lower cattle supplies. This is consistent with Cargill and Tyson’s permanent plant shutdowns in 2013 and 2015, respectively, at the bottom of a cattle inventory cycle.

5.2. New Plant

Let a new plant owned by firm \( B \) be built where plant 2 used to be located. The new plant, being owned by an entrant firm, has a potentially different cost structure from the existing plants owned by incumbent firm \( A \). This is very similar to how Cattlemen’s Heritage Beef Company is building a packing plant with capacity for 1,500 head per day near Glenwood, Iowa, which is less than 80 miles from the closed plant previously operated by Tyson in
Denison (Iowa Cattlemen’s Association, 2021). Firm A’s new maximization problem in response to this new plant involves the choice of \( r_I^1 \) and \( r_I^3 \) and is as follows:

\[
\max_{r_I^1, r_I^3} \Pi = (p - r_I^1) * q_1 - c(q_1) + (p - r_I^3) * q_3 - c(q_3) \tag{33}
\]

subject to \( q_1 (r_I^1, r_E^2, r_I^3) = \left( \frac{2r_I^1 - r_E^2 - r_I^3}{2\tau} + \frac{1}{3} \right) * M \)

and \( q_3 (r_I^1, r_E^2, r_I^3) = \left( \frac{2r_I^3 - r_I^1 - r_E^2}{2\tau} + \frac{1}{3} \right) * M \)

Still focusing on equal prices (i.e., \( r^I \)) at the incumbent firm’s two plants, the expressions for quantity supplied are exactly equivalent and depend on entrant firm’s price \( r_E^2 \):

\[
\max_{r^I} \Pi = 2 (p - r^I) * q - 2c(q) \tag{34}
\]

subject to \( q (r^I, r_E^2) = \left( \frac{r^I - r_E^2}{2\tau} + \frac{1}{3} \right) * M \)

Substituting the supply equations into the objective function, taking the first order condition with respect to \( r^I \), and equating it with 0, we simplify to obtain:

\[
p - 2r^I + r_E^2 - 2\frac{\tau}{3} - 2 \frac{\partial c}{\partial q} = 0 \tag{35}
\]

Now, turning to firm B’s optimization problem for the new plant 2:

\[
\max_{r_E^2} \Pi \left( r_E^2 \right) = (p - r_E^2) * q_2 - c_2(q_2) \tag{36}
\]

subject to \( q_2 \left( r_E^2, r^I \right) = \left( \frac{r_E^2 - r^I}{\tau} + \frac{1}{3} \right) * M \)

Plugging the supply function into the maximization problem, taking the first order condition with respect to \( r_E^2 \), and setting it equal to 0, we derive:
\[ p - 2r^E_2 + r^I - \frac{\tau}{3} - \frac{\partial c_2}{\partial q_2} = 0 \]  

(37)

The two first order conditions (35) and (37) give us a two-equation system with two unknowns. Solving for \( r^{I*} \) and \( r^{E*}_2 \), we obtain:

\[ r^{I*} = p - \frac{5\tau}{9} - \frac{1}{3} \left( 4 \frac{\partial c}{\partial q} + \frac{\partial c_2}{\partial q_2} \right) \]  

(38)

\[ r^{E*}_2 = p - \frac{4\tau}{9} - \frac{2}{3} \left( \frac{\partial c}{\partial q} + \frac{\partial c_2}{\partial q_2} \right) \]  

(39)

The most important takeaway from these optimal prices is that adding in a single plant owned by a different firm restores the correlation between downstream beef prices and fed cattle prices (i.e., the dependence on \( p \)). This suggests that new plants like the Cattlemen’s Heritage Beef Company plant strategically located near Glenwood, Iowa, could impact the behavior of the price spread. This is directly relevant for current policy discussions since on July 9, 2021, USDA announced that it would be allocating \$500 million to expand meat and poultry processing capacity in the United States. According to USDA’s initial press release, the funds will add slaughter capacity that “will help farmers, ranchers, farmworkers and consumers all get a fair shake” (USDA, 2021). If the definition of “fair shake” involves fed cattle prices that are more correlated with beef prices, this grant program could be effective in achieving that goal. Another insight from equations (38) and (39) is that the cost structure of the new plant enters into all cattle prices. Since the new plant’s cost structure could follow from USDA subsidies the plant receives, subsidy details will be consequential for both packers and producers. Hence, USDA should think carefully about the intended and unintended impacts of subsidy dispersion.

6. Conclusion
At some point since 2005, the largest beef packers in the United States began moving toward multi-plant coordination. This business practice is highly related to other often-discussed industry features such as concentration levels, geography and
transportation costs, alternative marketing arrangements, and cattle cycles and packing capacity. As we show, a beef packer employing multi-plant coordination can internally eliminate correlation between downstream beef prices and upstream fed cattle prices. Increased employment of this business practice by individual packing firms could explain persistently wide farm-to-wholesale price spreads at the aggregate level.

A question remains as to why beef packing firms have not always optimized profits at the firm level. Previous literature sheds some light on this puzzle. Summarizing surveys of 12 industries representing six countries, Scherer et al. (1975) find production cost savings opportunities associated with multi-plant coordination in most of the industries. These opportunities were not always capitalized on, however, with one provided explanation being that many firms were not able to overcome managerial difficulties associated with optimizing production across multiple plants. Managerial ability and its heavy reliance on effective information systems is deemed especially relevant to the beef packing industry due to the complex nature of fed cattle production and procurement. The rise in capability and use of computer technology in supply chain management since 1975, and especially since 2005, is likely the impetus for the use of multi-plant coordination. It is no coincidence that today beef packers are vulnerable to cybersecurity attacks such as the attack on JBS S.A. in the spring of 2021 that temporarily shut down all of its U.S. beef slaughter plants (Polansek and Mason, 2021). In other words, firm-wide cybersecurity attacks are not possible where there are no firm-wide information technology systems, and firm-wide systems are costly and therefore are not implemented without reason. This increased use of computer technology by multi-plant firms was predicted by Scherer et al. (1975) decades ago:

As the capacity of electronic data processing equipment grows and as persons trained to use that capacity analytically flow from the universities into industry, the ability of multi-plant, multi-product firms to solve complex production assignment and scheduling problems is bound to increase. One significant by-product may be an increase in the cost savings realizable through multi-plant operation... We nevertheless believe that there is much unmined gold left in the hills, and that multi-plant firms are going to develop better
ways of extracting it” (p. 397-398).

It seems that since 2005, beef packers have finally struck the mother lode and have figured out how to employ multi-plant coordination to extract it. It should not come as a surprise that many fed cattle producers desire substantial change.

As policymakers and politicians consider consequential actions for the beef supply chain, this study raises serious questions about the applicability of many market power studies performed before multi-plant coordination was effectively implemented. These studies may have been performed using methodology and data appropriate for the time, but care should be taken when extrapolating their results to the present day. Given the recent employment of multi-plant coordination and the new business environment that accompanies it, new data-driven are an absolute necessity to assess the impacts of market power. Governmental authorities should take the necessary steps to make available the data requisite for such studies.
References


