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COVID-19, Beef Price Spreads, and Market Power

Azzeddine Azzam and Sunil P. Dhoubhadel

The unprecedented spike in beef price spreads during the COVID-19-driven packing plant shutdowns prompted calls for investigations into "inappropriate influence" by packers in the beef market during the pandemic disruption. Using weekly data for the January 2010–August 2020 period and designating March–May 2020 as the disruption period, we estimate a structural oligopoly/oligopsony model using the generalized method of moments. We fail to reject the hypothesis of competitive pricing of beef and cattle.

Key words: meatpacking, plant shutdown, oligopoly, oligopsony

Introduction

The unprecedented spike in beef price spreads (Figure 1) and drop in cattle slaughter (Figure 2), as beef-packing plants closed or slowed production because of COVID-19 (Dyal, 2020; Taylor, Boulos, and Almond, 2020) prompted calls for investigations into "inappropriate influence" during the pandemic by the highly concentrated packers in the beef market (National Cattlemen's Beef Association, 2020; R-Calf, 2020; Grassley, 2020). When the pandemic hit, the top four packers (Tyson, Cargill, JBS, and National Beef) owned about half of the cattle slaughter capacity and processed more than 80% of the beef in the industry (Cattle Buyers Weekly, 2013; Stadheim, 2020).

The first plant to close was a JBS USA beef facility in Souderton, Pennsylvania, on March 31 (McCarthy and Danley, 2020). Although several other plants closed or slowed down throughout April, worries about the beef supply chain's disruption heightened with the closing of the JBS plant in Greeley, Colorado, on April 14. By then, beef production had declined from a peak of 565 million pounds during the week ending March 28 to 432 million pounds during the week ending April 11, a drop of 25% (Figure 1). As cattle were held up at feedlots, fed cattle prices fell but consumer demand surged because of meat shortage worries, leading to a rise in retail beef prices and a drastic increase in farm to wholesale price spread compared to the same period a year earlier (Figure 2). On April 28, John Tyson, the chairman of Tyson Foods, took out a full-page ad in *The New York Times*, *The Washington Post*, and *The Arkansas Democrat-Gazette* warning "the food supply chain was breaking" (Arkin, 2020).

President Trump issued an executive order the next day, declaring meatpacking plants to be "critical infrastructure." Subsequently, cattle slaughter bottomed out at 356 million pounds during the week ending May 2, a drop of 35% from the peak 5 weeks earlier (Figure 1). By the middle of May, daily plant capacity utilization declined as much as 45% (Cowley, 2020). Major grocery

Azzeddine Azzam (corresponding author) is the Roy and Judith Frederick Professor in the Department of Agricultural Economics at the University of Nebraska-Lincoln. Sunil P. Dhoubhadel is an assistant professor in the Department of Agriculture, Nutrition, and Human Ecology at Prairie View A&M University.
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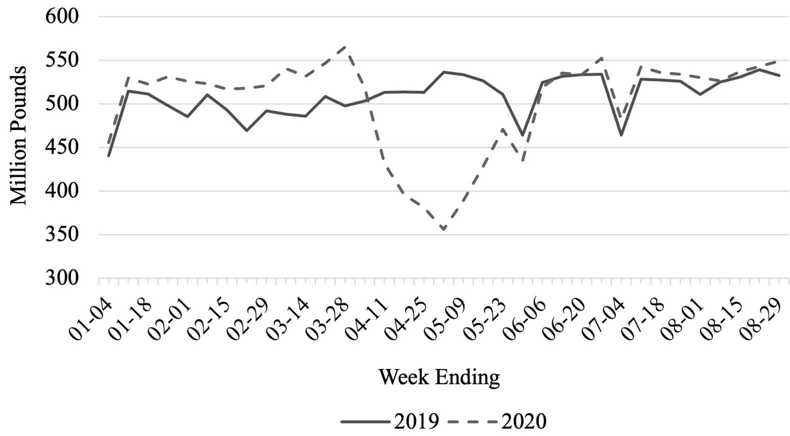

Figure 1. Weekly Federally Inspected Cattle Slaughter

Source: U.S. Department of Agriculture (2020c).

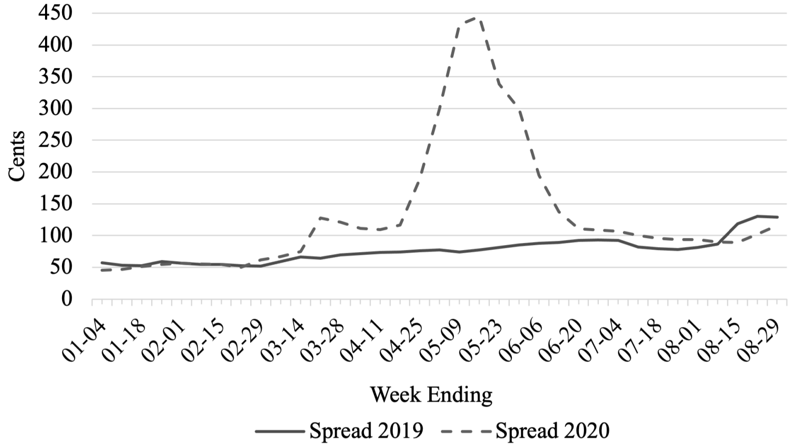

Figure 2. Comparative Farm-Wholesale Price Spreads, 2019–2020

Notes: Data provided by William Hahn.

chains, facing dwindling supplies, began to limit consumer purchases to curb hoarding (Fordham, 2020).

As more states eased shutdown measures in May, cattle slaughter recovered to its 2019 level of 533 million pounds by the week ending June 20 (Figure 1). Throughout the slaughter decline and recovery, the price spreads were inordinately above their 2019 level. They peaked at $4.45 during the week ending May 2, compared to 77.4 cents during the same week in 2019. They subsequently declined but remained considerably above their 2019 levels until mid-June (Figure 2).

The extent to which packer concentration and market power are believed to have triggered or exacerbated the widening of the beef price spread during the pandemic is revealed in a series of letters from cattle producer groups to lawmakers and lawmakers to government agencies. On March 31, 2020, Senator Chuck Grassley addressed a letter to the attorney general and the secretary of agriculture stating that “with the shelf price of meat at record highs and with the high rate of concentration in the meatpacking industry, there are concerns that the difference in these margins is the result of illegal practices” (Grassley, 2020). In a letter to President Trump on April 8, 2020, the National Cattlemen’s Beef Association (2020) asked that the USDA work with the Department of Justice to investigate whether “inappropriate influence” occurred in the meat markets. On April

29, 2020, R-Calf (2020) wrote to President Trump and congressional leaders stating that packer concentration "stymies producers' market access and robust competition for cattle... [and] also transfers any marketing power America's cattle farmers and ranchers might possess to the highly concentrated beef packing industry." On the same day, Senators Josh Hawley and Tammy Baldwin wrote to the Federal Trade Commission contending that the harms to the livestock industry due to COVID-19 "might have been mitigated if the meatpacking industry was less concentrated" (Hawley and Baldwin, 2020). One food industry watchdog alleged that, because of the high level of concentration in cattle slaughter, packers can increase profits by closing plants, explaining the rise in beef price spreads during the pandemic (Fassler and Brown, 2020).

It is not the first time the beef packing industry had to contend with plant closings due to shocks. However, no previous closures led to the degree of disruption in cattle slaughter caused by the pandemic and triggered heightened concern about market manipulation during the disruption. In 2013, Cargill closed a plant in Plainview, Texas, because of inadequate cattle supply due to drought. Although that closure wiped out 2%–3% of industry capacity (Gabbet, 2013) and idled 2,000 workers, it raised no alarms because the closure was attributed to slaughter overcapacity in the Texas panhandle (Vance, 2013). In August 2019, a fire severely damaged a Tyson plant in Holcomb, Kansas, knocking off 6% of the national fed cattle slaughter capacity (Spiegel, 2019). However, this time, beef price spreads rose to record levels, prompting the secretary of agriculture to direct the USDA Agricultural Marketing Service (AMS) to investigate potential market manipulation by packers following the Tyson plant fire.

On July 22, 2020, 5 months into the pandemic, the USDA released the *Boxed Beef & Fed Cattle Price Spread Investigation Report*, which summarized, in addition to the market impacts of the Tyson fire on beef price spreads, the market impacts of the COVID-19 pandemic (U.S. Department of Agriculture, 2020a). The report did not examine potential violations of the Packers and Stockyards Act (which is not within AMS's purview) but concluded that the behavior of the spread between the boxed beef price and fed cattle price did not preclude the possibility that packers violated the P&S Act.[1] As of this writing, academia has made some efforts to address that possibility, but they remain few and far between, and none address head-on the issue of market power during the pandemic.

Lusk, Tonsor, and Schulz (2021) also summarize market conditions before and during the pandemic but go a step further and estimate a reduced-form model where gross and net beef margins, constructed by the authors from secondary data, are regressed on the wholesale beef price and the cattle price, assuming perfect competition. The authors contend that although "it might seem strange to assume away the very issue that is at the center of attention (imperfect competition)" (p. 13), the reduced-form model results can only be rationalized by a competitive market structure. Specifically, based on the ratio of the wholesale price coefficient and the fed-cattle price coefficient (which turns out to be close to the dressing weight of 65.2%, implying that beef margins are biologically determined), the authors conclude that packer conduct is consistent with perfect competition.

In a qualitative study, Martinez, Maples, and Benavidez (2021) trace the effect of COVID-19 on cow–calf producers, stockers and backgrounding producers, and feedlot producers. They find that, although all producers have experienced losses, cow–calf producers are most vulnerable to COVID-19 in the long run. They report that, unlike the other two sectors, cow–calf producers are not margin operators, have high fixed costs, and relatively few price risk management tools suitable for their operations. Whether some of those losses can be attributed to noncompetitive pricing by packers during the pandemic was not considered.

Using time series models, Ramsey et al. (2021) compare pre-COVID-19 and COVID-19 vertical price transmission between weekly retail and wholesale beef prices. Although they find large price movements during the COVID-19 period they considered (April and May 2020), the movements returned a pre-COVID-19 speed of adjustment. The authors indicate that their estimates should not be interpreted as "reflecting competition (or lack thereof) or industry structure" (p. 449); rather,

[1] The violation would be "taking advantage of the [pandemic] situation through price manipulation, collusion, restrictions of competition, or other unfair practices" (U.S. Department of Agriculture, 2020a, p. 2).

the estimates "speak to the adjustment of the meat industry to shocks and resilience to economic disequilibria regardless of the underlying market structure."

This paper contributes to the emerging literature on COVID-19 and beef markets by developing and estimating a structural model of imperfect competition that explicitly addresses the question of whether some of the rise in beef price spreads during COVID-19 packing plant shutdowns and slowdowns can be explained by packer market power. The model's novelty is that it extends the demand rotation technique to identify oligopoly conduct (Bresnahan, 1982) to identify oligopoly and oligopsony conduct simultaneously by rotating wholesale beef demand and cattle supply.[2] Our finding suggests that the beef price spreads during the COVID-19 related to plant shutdowns/slowdowns were consistent with competitive performance, supporting the finding by Lusk, Tonsor,and Schutz (2021).

Theoretical Model

Building on the generic industry oligopoly model by Bresnahan (1982), the components of our oligopoly and oligopsony model of the beef packing industry are wholesale beef demand,

$$p_b = D(q_b, \boldsymbol{x}); \tag{1}$$

perceived marginal revenue,[3]

$$mr = D(q_b, \boldsymbol{x}) + \delta q_b D_{q_b}(q_b, \boldsymbol{x}); \tag{2}$$

cattle supply,

$$p_a = S(q_b, \boldsymbol{y}); \tag{3}$$

perceived marginal expenditure,

$$me = S(q_b, \boldsymbol{y}) + \mu q_b S_q(q_b, \boldsymbol{y}); \tag{4}$$

and cattle processing costs,

$$c = c(q_b, \mathbf{z}); \tag{5}$$

where p_b is the wholesale price of beef, p_a is the cattle price, q_b denotes both the quantity demanded and supplied—assuming a fixed proportional relationship between cattle and beef—and $\boldsymbol{x}$, $\boldsymbol{y}$, and $\boldsymbol{z}$ are the respective shifters of beef demand, cattle supply, and processing costs. The derivatives $D_{q_b} < 0$ and $S_{qb} > 0$ are the slopes of wholesale beef demand and cattle supply, respectively. The parameters δ and μ index the degree of oligopoly power in the wholesale beef market and the degree of oligopsony power in the cattle market, respectively. Both parameters range from 0 (perfect competition) to 1 (perfect cartel). Values of δ between 0 and 1 correspond to other oligopoly concepts. For μ, intermediate values correspond to other oligopsony concepts.

Equilibrium in the cattle market is established by equating the perceived derived demand to perceived marginal expenditure:

$$D(q_b, \boldsymbol{x}) + \delta q_b D_q(q_b, \boldsymbol{x}) - c_{q_b}(q_b, \boldsymbol{z}) = S(q_b, \boldsymbol{y}) + \mu q S_{q_b}(q_b, \boldsymbol{y}) \tag{6}$$

where $c_{q_b}(q_b, \boldsymbol{z})$ is marginal processing cost (mpc), yielding the equilibrium price spread:

$$p_b - p_a = -\delta q_b D_{q_b}(q_b, \boldsymbol{x}) + \mu q_b S_{q_b}(q_b, \boldsymbol{y}) + c_{q_b}(q_b, \boldsymbol{z}) \tag{7}$$

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[2] Past applications of the method to food industries focus one side of the market or the other, not both. Examples include Buschena and Perloff (1991), Azzam and Park (1993), Deodhar and Sheldon (1997), Muth and Wohlgenant (1999), and Çakır and Balagtas (2012).

[3] We assume away potential bilateral oligopoly between packers and wholesalers or retailers. In this sense, our model represents the least favorable scenario for market power in the industry.

or

$$m = -\delta\,(mr - p_b) + \mu\,(me - p_a) + c_{q_b}\,(q_b, \mathbf{z})\,. \tag{8}$$

Equation (8) indicates that if δ and μ are (statistically) 0, then the equilibrium spread is equal to marginal processing costs, as one would expect in a perfectly competitive industry.

Before switching to empirics, a few notes are in order. First, perceived marginal revenue (expenditure) is a linear combination of the observed beef (cattle) price and the monopoly (monopsony) marginal revenue (expenditure) curve. In the absence of imperfect competition, marginal revenue (expenditure), *mr* (*me*), is equal to the price of beef (cattle), p_b (p_a). Second, while the assumption of fixed proportions is widely used in modeling beef markets (Sexton and Xia, 2018), it precludes substitution between cattle and processing inputs (Wohlgenant, 2013). Whether Wohlgenant's criticism applies to our work hinges on how much flexibility packers had in reallocating inputs as they faced labor constraints in general and during the pandemic in particular. Third, while our model can be subject to the same criticisms leveled at static models of oligopoly and oligopsony (Hyde and Perloff, 1995; Corts, 1999), we should emphasize that δ and μ are parameters that capture a range of market performance and do not represent firms' expectation of the response of their rivals to their supply decisions, as in the case of conjectural variations. In a static environment, one cannot speak to firms' expectations of rivals' responses to their supply decisions.

Empirical Model

Since our focus is on oligopoly and oligopsony power before and during COVID-19-related disruptions to cattle slaughter, we first need to address whether we can identify the parameters δ and μ. As shown by Bresnahan (1982) in the oligopoly case, the parameter δ is identified by rotating as well as shifting the demand function. In the appendix, we use a simple model to illustrate how δ and μ can be identified by rotating as well as shifting beef demand and cattle supply, respectively.

Next, we need to delineate the time frame for the disruptions. Here we closely follow the U.S. Department of Agriculture (2020a) report, which defines the time frame as between February 23 and May 23, covering March, April, and May 2020. The period also coincides with the upward phase of the spread (Figure 2) and encompasses three critical dates that shaped the disruptions in the beef supply chain: March 11, the day the World Health Organization declared COVID-19 to be a worldwide pandemic; March 13, when COVID-19 was declared a pandemic in the United States and subsequent plant closings starting on April 1, and April 29, the day President Trump issued an executive order declaring meatpacking plants to be "critical infrastructure" ensuing plant re-openings. The sample period we use for estimation consists of weekly time-series observations of variables starting on the first week of January 2010 and ending in August 2020.[4]

Based on the deviations in the appendix, the expanded empirical version of the theoretical model is as follows:

$$\begin{aligned}\text{Wholesale beef demand: } q_{bt} &= d_0 + d_b p_{bt} + d_c p_{ct} + d_p p_{pt} + d_x x_t + d_{bx} p_{bt} x_t \\ &\quad + d_r norm + d_v covid + d_{\cos}\cos\frac{2\pi Q}{4} + \sin\frac{2\pi Q}{4} + e_{dt};\end{aligned} \tag{9}$$

[4] We bypassed data prior to 2010 because the previous decade spanning 2000–2009 was marred with several BSE cases that affected the U.S. beef market. August 2020 was the last month for which the weekly data provided to the authors by William Hahn at the Economic Research Service were available.

(10)
$$\text{Cattle supply: } q_{bt} = s_0 + s_a\left(\frac{p_{at}}{p_{rt}}\right) + s_g\left(\frac{cpl_{t-20}}{kh_t}\right) + s_{ag}p_{at}\left(\frac{cpl_{t-20}}{kh_t}\right) + s_r norm$$
$$+ s_v covid + s_z p_{zt} + s_{lag}q_{bt-1} + s_{\cos}\cos\frac{2\pi Q}{4} + \sin\frac{2\pi Q}{4} + e_{st};$$

(11) $$\text{Price spread: } m = \delta q_{bt}^D + \mu q_{bt}^S + mpc + e_{mt};$$

where

(11a) $$q_{bt}^D = \frac{q_{bt}}{d_b + d_{bx}x_t};$$

(11b) $$q_{bt}^S = \frac{q_{bt}}{s_a + s_{ag}\left(\frac{cpl_{t-20}}{kh_t}\right)};$$

(11c) $$m = p_{bt} - p_{at};$$

(11d) $$mpc = c_0 + 2 \times c_1\left(q_{bt} - \kappa\right);$$

(11e) $$\delta = \delta_0 + \delta_r norm + \delta_v covid;$$

(11f) $$\mu = \mu_0 + \mu_r norm + \mu_v covid.$$

The dependent variable in the wholesale beef demand equation (9) is the quantity of federally inspected slaughter, q_b. The right-hand-side variables include the wholesale price of beef, p_b; price of chicken, p_c; price of pork, p_p; expenditures on food-away-from-home (FAFH), x; and its interaction with the price of beef. As shown in the appendix, the interaction is needed to identify oligopoly conduct. The dummy variable *covid* takes a value of 1 during the plant shutdown period (March, April, and May 2020) and 0 otherwise. The dummy variable *norm* takes a value of 1 during the corresponding 3 months each year in the sample. We model the usual quarterly seasonality of cattle supply by trigonometric variables, with Q denoting the quarter of the year.

We expect wholesale beef demand to be inversely related to the wholesale price of beef. Poultry and pork are the usual meat substitutes. Expenditures on FAFH measure the amount of income spent on dining out and, for the pandemic's duration, serve as a proxy for restaurant closures. The effect of FAFH expenditures on beef demand is ambiguous as an increase in restaurant beef demand can cut some of the grocery store beef demand and vice versa. The effect of the interaction of expenditure with the beef price is also ambiguous. It can be positive or negative, resulting in a flatter or steeper demand curve. The dummy variable *covid* allows comparing the 3 months of supply chain disruption in 2020 with the same 3 months in the whole sample during "normal" times and is expected to shift beef demand upward during the disruption period because of panic-buying. The other dummy variable, *norm*, allows comparing reference months (March, April, and May) to the rest of the year during the sample period. The subscript t denotes week, and e_d represents the stochastic error.

Federally inspected slaughter, q_b, is also the dependent variable in the cattle supply function (10). The explanatory variables include lagged slaughter volume to capture partial adjustment in cattle supply (Marsh, 1994) or asset fixity (McKendree et al., 2020); the cattle and corn price ratio, $\frac{p_{at}}{p_{rt}}$ (with corn being a major feed); the ratio of cattle placed on feed 5 months (or 20 weeks) ago, cpl_{t-20}; current industry slaughter capacity in head, kh_t, capturing the congestion in the cattle slaughter pipeline; and the interaction between p_a and $(\frac{cpl_{t-20}}{kh_t})$ to identify oligopsony conduct (see the appendix). Traditionally, researchers model cattle supply as a function of past cattle placements without considering the industry's capacity to harvest those placements. Implicit in the approach is the assumption of no congestion in cattle slaughter. The assumption is questionable considering COVID-19-related plant shutdowns. Our approach accounts for such congestion, though

Table 1. Variables, Definitions, and Data Sources

Variables	Definitions	Data Source
p_b	Wholesale value on a retail weight basis (cents)	William Hahn[a]
p_a	Net farm value on a retail weight basis (cents)	William Hahn
q_b	Federally inspected cattle slaughter quantities (million lb)	U.S. Department of Agriculture (2020c)
p_c	National composite broiler price (cents/lb)	Livestock Marketing Information Center (2020)
p_p	Pork cutout values ($/cwt)	Livestock Marketing Information Center (2020)
p_r	Corn Kansas City price ($/bush)	Livestock Marketing Information Center (2020)
x	Food away from home sales ($millions)	U.S. Department of Agriculture (2020b)
cpl_{t-20}	Cattle placed on feed 5 months ago (head)	U.S. Department of Agriculture (2020c)
k_q	Industry plant capacity in pounds: 3-year max cattle slaughter (million lb)[b]	Authors[c]
Instrumental variables[d]		
kh	Industry plant capacity in head: 3-year max cattle slaughter (head)[a]	Authors[c]
p_z	Weekly U.S. No 2 diesel retail prices ($/gallon)	U.S. Energy Information Administration (2020)
$lagq_b$	One period lag of q_b	
$norm$	Dummy variable for normal months (March, April, and May)	
$covid$	Dummy variable for COVID-19 disruption (March, April, and May 2020)	
$qrtr$	Dummy variable for the quarter	
$xcos$	$\cos(1/2 \times \pi \times qrtr)$	
$xsin$	$\sin(1/2 \times \pi \times qrtr)$	
$holcom$	Dummy for Tyson Holcom Kansas plant fire (August 10–November 9, 2019)	
$lagp_b$	One period lag of p_b	
$lagp_a$	One period lag of p_a	
$wage$	Monthly average hourly earnings of production and nonsupervisory workers	Federal Reserve Bank of St. Louis (2020a)
cpi	Consumer price index for all urban consumers	Federal Reserve Bank of St. Louis (2020b)

Notes: [a]Data provided by William Hahn, an agricultural economist with the USDA ERS.
[b]Since we use the ratio of cattle placements and capacity in head as a proxy for congestion in the cattle supply function, kh is adjusted for plant shutdowns using data provided by Cowley (2020). The capacity variables kq is not adjusted because marginal cost is defined in terms of deviations of actual cattle slaughter from full capacity.
[c]We follow Tonsor and Schulz (2020) in constructing the capacity variables.
[d]Instrumental variables used in GMM estimation of equations (7)–(9).

imperfectly, as we describe below. Like wholesale beef demand, we include the dummy variables *covid* and *norm* to compare the 3 months of cattle-slaughter disruption in 2020 with the same 3 months during normal years. e_d represents the stochastic error.

We expect cattle supply to respond positively to a rise in the cattle–corn price ratio, positively adjust to lagged cattle supply, and shift leftward during the COVID-19 during months of plant shutdowns. In theory, congestion should slow down cattle flow to slaughter plants, particularly when some plants shut down or slow down, as occurred during COVID-19. In practice, however, the effect is ambiguous. Our congestion variable does not account for possible countervailing factors for which information is unavailable, such as inter-plant cattle transfers during plant shutdowns, additional shifts and overtime, slaughter line speed, and slaughter during weekends.

Table 2. Descriptive Statistics (*N* = 553)

Variables	Mean	Standard Deviation	Minimum	Maximum
Retail equivalent wholesale beef value (cents/lb)	318.17	50.46	214.47	697.76
Retail equivalent farm value (cents/lb)	265.07	39.63	178.91	371.96
Farm-to-wholesale price spread (cents/lb)	53.10	38.98	12.34	444.90
FI slaughter quantities (million lb)	488.17	36.41	321.20	565.10
Slaughter capacity (million lb)	536.80	13.04	512.30	565.10
Adjusted slaughter capacity (head)	674,230	33,418	430,843	722,100
Cattle placed on feed with 5 months lag (head)	1,876,320	248,331	1,431,000	2,521,000
Broiler price (cents/lb)	89.84	12.00	50.00	121.09
Pork wholesale price (cents/lb)	84.79	13.38	53.55	136.11
Corn price ($/bu)	4.56	1.51	2.65	8.36
Diesel price ($/gal)	3.20	0.60	1.98	4.16
Food away from home sales ($millions)	14,162.83	2,331.86	8,918.02	18,788.90

On the left-hand side of equation (11) is the spread, m, defined by equation (11c). While the theoretical model clearly shows that the equilibrium spread, under the assumption of fixed proportional relationship between beef and cattle, is the difference between the prices packers receive from selling a unit of beef to wholesalers and the prices they pay for procuring an equivalent unit of cattle from cattle feeders, precise corresponding data are not available. What is available and widely used in research is the beef farm-to-wholesale price spread. Constructed by the U.S. Department of Agriculture (USDA) Economic Research Service (ERS) on the basis of a standard steer, the spread represents the difference between the wholesale price and the net farm price (the difference between the gross farm price and the value of byproducts), both measured in retail equivalents (U.S. Department of Agriculture, 2020b).[5] However, as explained by Hahn (2004, p. 6), since each animal that a packer harvests differs in quality and type, technically, each animal has its own farm-to-wholesale price spread:

> In the best-case scenario, the ERS farm-to-wholesale price spread represents the average gross margin for its standard animal. The price spread may be higher or lower than packers' total gross margins; still, [the] price spreads, and packer gross margins are likely to be highly correlated.

On the right-hand side of equation (11), the variables q_b^D (11a) and q_b^S (11b) represent time-varying slopes of wholesale beef demand and cattle supply, respectively, allowing identification of δ and μ (see the appendix). Equation (11c) is the identity for the spread. Absent data on actual industry processing costs, we parametrize marginal processing cost, *mpc*, in equation (11d) by assuming the U-shaped beef processing cost function takes the form $C_t = c_0 q_{bt} + c_1(q_{bt} - \kappa)^2$ (Vives, 1986; Nishimori and Ogawa, 2004), where κ denotes industry processing capacity. The specification ensures that the long-run average processing cost, *apc*, is at a minimum and equal to the marginal processing cost, c_0, at full production capacity.[6] Equations (11e) and (11f) parametrize oligopoly and oligopsony conduct as functions of the dummy variables *norm* and *covid*. That allows a comparison of market power during COVID-19 months with the corresponding normal months during the sample period. e_m is the stochastic error. Table 1 lists the variables and the instruments used in the estimation, their corresponding definitions, and data sources. Table 2 provides the descriptive statistics of the variables in the structural model.

[5] For a recent review of definitions, measurement, uses (and misuses), and suggested changes in constructing and explaining price spreads, see Schroeder et al. (2019).

[6] $apc = c_0 + c_1(q_{bt} - 2k + \frac{k^2}{q_{bt}})$. At full capacity $q_{bt} = k, apc = c_0 = mpc$.

Table 3. Summary of Model Estimates and Standard Errors (COVID-19 period: March–May 2020)

Constants/Variables/Test	Parameter	Estimate	Standard Error	*p*-Value
Demand (7)				
Constant	d_0	765.724	74.083	<0.0001
p_b	d_b	−2.041	0.395	<0.0001
p_c	d_c	−4.781	1.173	<0.0001
p_p	d_p	5.113	1.271	<0.0001
x	d_x	−9.8E-3	4.56E-3	0.0316
$p_b \times x$	d_{bx}	1.11E-4	2.1E-5	<0.0001
norm	d_r	7.955	11.505	0.4896
covid	d_v	50.440	35.696	0.1582
xcos	$d_{\cos}$	−12.729	8.130	0.1180
xsin	$d_{\sin}$	22.696	9.785	0.0207
Supply (8)				
Constant	s_0	−168.133	101.6	0.0985
p_a/p_r	s_a	2.432	0.969	0.0124
cpl_{t-20}/kh	s_g	165.107	27.250	<0.0001
$p_a \times (cpl_{t-20}/kh)$	s_{ag}	−0.390	0.141	0.0059
p_z	s_z	60.282	19.922	0.0026
$lagq_b$	s_{lag}	0.286	0.085	0.0009
norm	s_r	−4.779	9.070	0.5985
covid	s_v	−94.395	35.419	0.0079
xcos	$s_{\cos}$	−0.603	4.258	0.8873
xsin	$s_{\sin}$	−17.412	8.182	0.0338
Spread (9)				
Marginal processing cost				
Constant	c_0	83.725	37.834	0.0273
$(qb - kq)$	c_1	0.271	0.103	0.0092
Oligopoly conduct				
Constant	δ_0	−0.001	0.003	0.7104
norm	δ_1	0.023	0.015	0.1294
covid	δ_2	−0.884	0.482	0.0672
Oligopsony conduct				
Constant	μ_0	0.011	0.022	0.5900
norm	μ_1	0.033	0.030	0.2787
covid	μ_2	−1.437	0.738	0.0520
Over-identification test		10.84		0.2108

Results

We estimate equations (9)–(11) simultaneously using the generalized method of moments (GMM). GMM is a better estimator for large samples, does not require distributional assumptions about the error terms, and yields estimates robust to heteroskedasticity and autocorrelation (Gallant, 2009). However, the validity of inference hinges on the instruments' validity, verified using the overidentifying restrictions test. The test is asymptotically distributed as a χ^2 with $r - p$ degrees of freedom, where r is the number of instruments times the number of equations and p is the number of parameters (SAS Institute, Inc.). Table 3 lists the parameter estimates, standard errors, and p-values for each equation. The over-identifying restrictions test is in the last row of the table. With a p-value of 0.2108, we cannot reject the hypothesis that the restrictions are valid.

Looking at the beef demand equation, 7 of the 10 parameter estimates are statistically significant at the 5% level or better. The parameter estimates d_b, d_c, and d_p show that demand is downward sloping, and pork is a substitute as expected, but poultry turns out to be a complement rather than a substitute. It may be a consequence of using weekly data, a short window for capturing the full extent of substitution between beef and chicken. The estimate d_x indicates that food expenditures away from home lower beef demand, implying that the decline in restaurant dining due to COVID-19 has increased overall beef demand. The parameter d_{bx} shows that the demand rotation needed to identify oligopoly conduct is statistically different from 0 and positive. Both d_r and d_v are positive but not statistically significant at the conventional levels, though d_v points to a moderately significant upward shift in demand during the disruption.

Of the 10 parameter estimates of the cattle supply equation, 8 are statistically significant from 0. The slope s_a is positive as expected. The parameter estimate s_g is positive and highly significant. The sign is contrary to what one would expect from a rise in congestion, suggesting that other factors (e.g., additional slaughter shifts during weekends and transfer of cattle from congested plants to less crowded plants) are at play in keeping cattle in the slaughter pipeline. The rotation needed to identify oligopsony conduct is statistically different from 0 and negative, as indicated by the p-value of s_{ag}. The coefficient of diesel's price is of the opposite sign than expected and highly significant. The point estimate on the partial adjustment coefficient s_{lag} is consistent with the slow adjustment in producing fed cattle. The sign and statistical significance of S_v indicate a downward shift in cattle supply March–May 2020 period. No supply shift is statistically evident during the same months in normal years.

As expected, the two-parameter estimates of marginal processing cost in the spread equation are both positive and statistically significant. The estimate of c_0 suggests that at full capacity, the marginal processing cost is about \$0.84/lb. The estimate of c_1 is consistent with marginal cost below (above) average cost when the industry is operating below (above) capacity. The data in our sample suggests that the industry has consistently operated below full capacity by an average of 48 million pounds during the whole sample period, 47 million pounds during March to May for pre-COVID years, and 97 million pounds during the COVID-related plant shutdowns. The implied marginal (average) costs in cents per pound for the respective periods are 57.76 (85.14), 58.31 (85.14), and 31 (89.19). Since actual data on plant-level processing costs are not available, we cannot gauge econometric estimates' accuracy. Still, they do fall within the ranges of observed spreads, suggesting they may not be unrealistic. The respective actual beef-price spread ranges, in cents per pound, for the whole sample period, the pre-COVID period, and the COVID period are [12.3, 444.9], [12.34, 299.2], and [61.48, 444.9] cents per pound.

Table 4 presents test results under the null hypothesis of perfect competition in the beef and cattle markets, respectively, using four alternative configurations of the dummy variables in equations (11e) and (11f). The first configuration switches the dummy variables *norm* and *covid* to 0 (i.e., no regime switch during the March–May period during each year in the sample). Thus, the oligopoly (market power in beef selling) and oligopsony (market power in cattle buying) indices are respectively measured by δ_0 and μ_0. The rest of the indices can be similarly derived by switching the

Table 4. Test Results under the Null Hypothesis of Competitive Conduct

March–May		Oligopoly Conduct (market power in beef selling)			Oligopsony Conduct (market power in cattle buying)		
normal	*covid*	**Index**	**Estimate**	**CI**	**Index**	**Estimate**	**CI**
0	0	δ_0	-0.001 (0.004)	[-0.009, 0.006]	μ_0	0.012 (0.022)	[-0.031, 0.055]
1	0	$\delta_0 + \delta_r$	0.021 (0.014)	[-0.198, 0.241]	$\mu_0 + \mu_r$	0.045 (0.049)	[-0.051, 0.141]
0	1	$\delta_0 + \delta_v$	-0.886 (0.483)	[-1.833, 0.066]	$\mu_0 + \mu_v$	-1.426 (0.728)	[-2.853, 0.001]
1	1	$\delta_0 + \delta_r + \delta_v$	-0.863 (0.478)	[-1.799, 0.074]	$\mu_0 + \mu_r + \mu_v$	-1.393 (0.713)	[-2.790, 0.004]

Notes: Values in parentheses are standard errors. All the tests in this table are against values of $\delta = 0$ and $\mu = 0$ (i.e., the null hypothesis is perfect competition).
$\delta_0 = 0$ and $\mu_0 = 0$ index market power for the whole sample period.
$\delta_0 + \delta_r$ and $\mu_0 + \mu_r$ index market power for the March–May period in the sample.
$\delta_0 + \delta_v$ and $\mu_0 + \mu_v$ index market power for the 2020 COVID-19 March–May period in the sample.
$\delta_0 + \delta_r + \delta_v$ and $\mu_0 + \mu_r + \mu_v$ index market power for the March–May period, including the 2020 March–May COVID-19 period.

appropriate dummy variables on and off: For example, $\delta_0 + \delta_r$ and $\delta_0 + \delta_v$ denote oligopoly indices during March–May months in the sample and 2020 COVID-19 March–May months, respectively. We provide the point estimate, standard error, and 95% confidence interval (CI) for each index. As shown by the CIs in Table 4, we not only fail to reject that the indices are 0 in all cases, but even the largest upper-end value of CIs (0.24) is far away from 1 (i.e., collusion). In other words, beef processor conduct during COVID-19 and in normal years is no different from perfect competition.[7]

Summary and Conclusion

This paper contributes to the emerging literature on COVID-19 and beef markets by addressing whether some of the spike in beef price spreads during the COVID-19-related disruption to cattle slaughter can be explained by packer oligopoly and oligopsony conduct. We extend Bresnahan's (1982) generic model for identifying industry oligopoly conduct to identifying industry oligopoly as well as oligopsony conduct. Using weekly data from January 2010 to August 2020 and designating March–May 2020 as the period of COVID-19 disruption to cattle slaughter, we estimate the model using the generalized method of moments. We cannot reject the hypothesis of competitive beef price spreads during the COVID-19 disruption based on our results. Our finding is in line with that of Lusk, Tonsor, and Schulz (2021), noting that they used a different price series, considered a different time period, and inferred perfectly competitive behavior by the beef packers during COVID-19 without explicitly testing for market power.

In light of the current level of concentration in the U.S. beef packing industry, it is reasonable to claim that the dramatic increase in the farm-to-wholesale price spread during COVID-19-driven disruptions to cattle slaughter is due to concentration-driven market power. The econometric evidence in our study does not (statistically) support such a claim. That leaves a rise in processing costs as the most likely driver of the increase in the beef price spread during COVID-19 plant shutdowns and slowdowns.

That said, the jury is still out pending further research using alternative empirical methods and datasets to examine beef industry conduct during COVID-19 and other food industries that faced

[7] We explored the robustness of the market power results to including June 2020 in the COVID-19 period. Extending the period affected the confidence intervals of the index of cattle of buying power during the March–June period and the index of oligopsony power for the whole sample period, without affecting the test of market power. Both confidence intervals were in the negative range at the 95% confidence level but contain 0 at a higher level of confidence.

bottlenecks during the pandemic. As we indicated, the technique we use in this paper has limitations, as with any of the different empirical industrial organization approaches. Still, the method is useful and easy to implement for inferring departures from a perfect competition when only aggregate industry data are available.

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Appendix

Let beef demand, cattle supply, and processing costs, respectively, take the simplified linear forms

(1′) $$q_b = d_0 + d_b p_b + d_x x,$$

(3′) $$q_b = s_0 + s_a p_a + s_y y,$$

(5′) $$mpc = c_0 + c_b q_b,$$

where x and y are shifters. The implied perceived marginal revenue and perceived marginal expenditure are given by

(2′) $$mr = p_b + \delta \frac{q_b}{d_b}$$

and

(4′) $$me = p_a + \mu \frac{q_b}{s_a}.$$

Substituting the two expressions in equation (6) yields the price spread equation

(6′) $$m = c_0 + \gamma q_b,$$

where $\gamma = c_b - \frac{\delta}{d_b} + \frac{\mu}{s_a}$. While equation (6′) can be estimated, we cannot disentangle the conduct parameters and the slope of the marginal processing cost function from the estimate of γ even if we use the slopes of equations (1′), (3′), and (5′). That would continue to be the case even if marginal processing cost were assumed to be independent of output $(c_b = 0)$, unless either δ or μ is set to 0, as has been the case in past empirical applications.

Identifying the conduct parameters requires shifting and rotating the demand and supply schedules. That is accomplished by interacting p_b and x in the demand equation and p_a and y in the supply equation. The new demand, supply, and price spread equations are rewritten as

(1″) $$q_b = d_0 + d_b p_b + d_x x + d_r p_b.x,$$

(3″) $$q_b = s_0 + s_a p_a + s_y y + s_r p_a.y,$$

(6″) $$m = c_0 - \delta q_b^D + \mu q_b^S + c_b q_b,$$

where

(11a″) $$q_b^D = \frac{q_b}{d_b + d_r x},$$

(11b″) $$q_b^S = \frac{q_b}{s_a + s_r y}.$$