

Game Theory Application to Fed Cattle Procurement in an Experimental Market

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ABSTRACT

Consolidation in meatpacking has elicited many market power concerns and studies. A noncooperative, infinitely repeated game theory model was developed and an empirical model estimated to measure beef packing firm behavior in cattle procurement. Experimental market data from three semester-long classes using the Fed Cattle Market Simulator (FCMS) were used. Collusive behavior was found for all three data periods though the extent of collusion varied across semester-long data periods. Results may have been influenced by market conditions imposed on the experimental market in two of the three semesters. One was a marketing agreement between the largest packer and two feedlots and the other involved limiting the amount and type of public market information available to participants. Findings underscore the need for applying game theory to real-world transaction-level, fed cattle market data. [EconLit Citations: C730, L100]. © 2009 Wiley Periodicals, Inc.

1. INTRODUCTION

Comprehensive literature reviews identify many studies related to noncompetitive behavior of meatpacking firms (Azzam & Anderson, 1996; Ward, 2002; Whitley, 2003). The high four-firm concentration ratio in steer and heifer procurement, i.e., near to or exceeding 80% since 1990 (Grain Inspection, Packers and Stockyards Administration, 2007), is a primary structural characteristic in meatpacking leading to charges of noncompetitive behavior. A similarly high concentration ratio exists for wholesale beef sales as well.

Previous studies differ significantly in data aggregation, data period length, and methodology chosen (see summary table in Ward 2002). Several studies attempted to link industry structure with performance, following the traditional structure-conduct-performance (SCP) paradigm attributed to Bain (1951). Much of the SCP empirical work was based on the price-concentration hypothesis, namely, that output (input) prices increase (decrease) with increasing seller (buyer) concentration. Critics of the SCP approach cite its failure to have a solid theoretical foundation. Empirical applications have been questioned regarding the measurement of key variables, causality direction between prices or profitability and concentration, and model specification (Azzam & Anderson, 1996).

The more common approach in recent literature is new empirical industrial organization (NEIO), which links firm behavior more directly with firm or industry performance. Most NEIO research involves estimating a conjectural variation (CV), thereby tying a specific type of firm conduct or behavior to performance. Since the initial application of this approach to the meatpacking industry by Schroeter (1988), several studies have relied on similar methodology. However, NEIO is not without criticism; such as its use of aggregated data, potentially unrealistic assumptions about firm conduct, static nature of the analysis, and functional form in models estimated (Azzam & Anderson, 1996; Hunnicutt & Weninger, 1999; Sexton, 2000).

An extension of the NEIO approach with application to beefpacking procurement includes concepts from game theory (Koontz, Garcia, & Hudson, 1993; Koontz & Garcia, 1997). Use of game theory allows the repeated strategic interaction of packers to be modeled more fully and provides a theoretical basis for observed behavior. The objective of this paper is to develop and estimate a game-theoretic model of industry conduct and supergame strategies in a dynamic oligopsony using experimental market data.

This research extends previous game theory applications to fed cattle procurement. Experimental market data are more detailed than available industry data used in prior game theory applications. Results presented here from an experimental market have significance for further investigations of meatpacking firm behavior by regulatory agencies and further research by economists. Implications include, most importantly, the need to use detailed, transaction-level data from the real-world fed cattle market for game theory model estimation.

2. THEORETICAL FOUNDATION

Friedman's (1971) specification provides an appropriate basis for modeling beefpacker behavior in a fed cattle procurement market.¹ This section discusses elements of the Friedman specification believed to be relevant to the beefpacking industry.

A single period, noncooperative ordinary procurement game consists of a fixed, finite set of beefpacking firms, which cannot enter into binding agreements. In such a game, each player (firm) is aware of the strategy sets and payoff functions applicable to all participants but is not able to completely observe the strategic decisions made by others. Players thus have complete but imperfect information.

The quantity of fed cattle purchased is the assumed strategic variable in the procurement game and the strategy set for the overall game consists of all possible quantities procured for all packers in a single period. The profit payoff to the i^{th} player from processing fed cattle into boxed beef is a function of its own strategy as well as those of other players. Interdependence indicates the volume of cattle procured by each packer affects the volume available to the remaining packers, which, in turn, affects their payoff.

Nash equilibrium exists when each packer maximizes its payoff with respect to its own choice of strategy, given the strategy choices of other players in the game. Friedman (1971) noted that when payoff functions are profit functions, the players are firms, and the strategy choices are quantities, the game is a single period

¹Mathematical development of the theory can be found in Carlberg and Ward (2002).

oligopoly, and the noncooperative (Nash) equilibrium is the same as the Cournot quantity-setting solution. Under the Cournot solution, firms take each rival's output as given, and a change in the quantity purchased by one firm has no effect on the quantities purchased by other firms.

Packers in a single period game choose a quantity to achieve static profit maximization, but this strategy may not hold for a repeated game in which the same ordinary game is played at each iteration (Friedman, 1986). If players are able to tacitly collude in a multi-period game, they may be able to achieve profits in excess of those generated in a single period game. The Nash equilibrium of a single period game can differ substantially from that which prevails in a repeated game because alternative strategies can produce higher payoffs than in a single period game.

A sequence of ordinary games with individual player strategy sets and payoff functions allows for the association of differing strategies and payoffs across time. Players seek to maximize their payoffs over multiple periods for a given discount parameter. Because all players' past strategies form part of the information set available to each player, the strategy chosen by each player in the current period is some mapping of the strategy vectors of players in previous periods. In the beefpacking industry, past fed cattle purchase prices and volumes of rivals, to the extent they are known for individual firms or the aggregate market, are taken into account when setting quantity in the current procurement period.

The concept of a trigger strategy is central to the idea that packers can tacitly collude to keep fed cattle prices from approaching those that would prevail in a competitive market. A trigger strategy facilitates collaboration between players and allows them to achieve cooperative (cartel) outcomes in games that have a noncooperative structure. A trigger strategy is a tacit agreement in each period to choose a strategy vector resulting in lower fed cattle prices than those which would occur in the ordinary game where each player chooses a Cournot strategy.

Any player can increase its single period payoff for any iteration within the supergame by choosing a defection strategy. In beefpacking procurement, a defection strategy would see player i pay slightly higher than the collusive price for fed cattle, thus increasing its processing volume. If any player defects from the tacitly collusive strategy vector, it triggers a reversionary (noncooperative) episode in which other players who observe that market prices have risen above some trigger level must follow suit. As a result, all players choose the noncooperative strategy for each remaining time period. Because all players opt for a strategy resulting in the lowest price paid across each ordinary constituent game, there is no incentive for a player to defect as long as the chosen strategy exceeds the ordinary game strategy plus the discounted payoff.

Beefpacking procurement behavior is believed to exhibit patterns consistent with periodic reversionary episodes. Based on the Green and Porter (1984) model, these episodes occur because cattle supply fluctuations are not directly observed by firms and not due to defection by any of the cartel members. Green and Porter (1984) assert that the reversionary period does not necessarily last for the remainder of the game after defection, but instead is T ordinary game periods in length. The number of ordinary game periods depends on the amount by which the trigger price and market price differ in the first reversionary period.

If one or more packers choose a defection strategy, the fed cattle market enters a reversionary period. The aggregate procurement volume for packer i from this

strategy may not equal the cooperative strategy and payoff in normal (nonreversionary) periods. Each packer's expected payoff in reversionary periods is the expected discounted return to packer i in a single-period Cournot environment plus the discounted gain in returns due to participation in the cartel. Then the Nash equilibrium stated as a trigger strategy equilibrium means that no strategy can produce a higher payoff for players than the trigger strategy. The associated first order condition for this expression indicates the marginal return to defecting from collusive output levels must be exactly offset by the risk of suffering a loss in returns by triggering a reversionary episode of length T .

A resulting implication is that the observed market price reveals information about supply only and does not cause players to revise their interpretation of what their competitors have procured. Industry reversion from collusive states would occur regardless of actual intentional defections by cartel members. The critical extension of this result is that although participants are aware reversionary episodes occur as a result of supply conditions rather than intentional defection, it is rational for them to participate in the episodes anyway. If firms failed to participate in the reversionary episodes when high prices prevailed due to low fed cattle supply conditions, the first order condition would not hold during normal game periods and collusive behavior would not be optimal for individual packers.

The beefpacking industry can be expected to exhibit both reversionary and collusive periods. Reversionary periods may result either from unanticipated fluctuations in the supply of fed cattle causing higher prices, which appear as defections, or from actual choice of a defection strategy by an individual packing firm. If plant shutdown costs are sufficiently high, firms may purposely choose a defection strategy as their optimal strategy. When packers experience periods of small fed cattle supplies, the reversionary period length will be short.

3. EXPERIMENTAL MARKET DESCRIPTION AND DATA

Plant-specific, transaction-level data for fed cattle are confidential and not publicly available. Generally, such data cannot be accessed without congressional or regulatory authority due in part to industry consolidation, proprietary nature of the data, and either pending or potential civil antitrust litigation.

Limited access to detailed market data led a team of economists to develop the Fed Cattle Market Simulator (FCMS). As noted by Ward, Koontz, Peel, and Trapp (1996), the FCMS integrates features of business simulation (Gentry, 1990) and experimental economics (Plott, 1982). The market simulator generates plant-specific, transaction-level data similar to that not publicly available for research. The empirical application of game theory to beefpacking procurement utilized data from the experimental market. Therefore, an understanding of the structure, operation, and economic behavior of participants in the experimental market is important.

The FCMS was designed to resemble a real fed cattle procurement region in which there are typically several cattle feedlots (sellers) and only a few packers (buyers). The experimental market consists of four packing firms of different sizes and eight feedlots of nearly equal size. Packer and feedlot teams of 2–4 people trade paper pens of fed cattle, each sheet of paper representing 100 head of steers. Participants trade in 7-minute, open negotiation sessions with each trading period representing 1 week of real time business. Participants negotiate cash (spot) or forward contract

transactions, and may either hedge or speculate in the futures market component of the experimental market. Individual packing firms are aware of their efficient (minimum cost) procurement volumes, which for packers one through four are 8, 9, 11, and 12 pens per trading period, respectively. Output (boxed beef) price is determined by the volume of fed cattle processed, both number and weight of fed cattle. Packers use the most recent boxed beef price to determine their breakeven bid or price bid with a specified target margin. Cattle feeders use known feeder cattle and grain costs to determine their breakeven offer prices for various weights of fed cattle.

Market-ready fed cattle are placed on a 'show list' for the packers at 1100 pounds and continue to gain 25 pounds per week until they are sold, somewhere between 1100 and 1200 pounds. The number of new placements on the show list follows a preprogrammed, irregular but somewhat cyclical pattern, similar to a cattle cycle in the beef industry. Thus, at times, supplies are plentiful and each packer can reach its minimum cost volume relatively easily; and as a group, packers have the negotiating advantage over price (Ward, 2005). At other times, fed cattle supplies are tight relative to packing capacity and each packer finds it difficult to purchase its minimum-cost volume. During these tight-supply periods, negotiating strength in the market shifts to cattle feeders. This finding parallels the asymmetric bargaining power argument of Zhang and Sexton (2000).

Considerable market and performance information is provided to market participants during and after each trading session. This information parallels what is available to the real fed cattle market by the U.S. Department of Agriculture's Agricultural Marketing Service (AMS) and National Agricultural Statistics Service (NASS) and from the Chicago Mercantile Exchange (CME). Current market data (e.g., volume and price range) on the most recent cash market and futures market transactions are continuously scrolled across an electronic information display during each trading period. End-of-week summary information (weekly volume and average prices for fed cattle, feeder cattle, and boxed beef) is posted each week. Cattle on feed reports are issued every 4 trading weeks. Income statements are provided to each packer and feedlot firm during the short intervals between trading sessions. Participants can access private information from other teams depending on their need for information and willingness of rival teams to divulge the information. Such a scenario, which Fama (1970) refers to as strong form information efficiency, may be necessary for packers to behave noncompetitively.

Research reported here used data from three semester-long classes (1994, 1995, and 1996), each of which used the FCMS weekly throughout the semester. In two of the three semesters, a designed experiment was imposed on the experimental market. In 1995, researchers estimated impacts from imposing a marketing agreement between the largest packer and the two largest feedlots at two, 16-week intervals (Ward, Koontz, Dowty, Trapp, and Peel, 1999). Student teams received cash awards for their profit performance during randomly selected periods, as suggested for experimental economics research (Friedman & Sunder, 1994). In 1996, researchers varied the amount and type of information available to participants in randomly selected, 4- to 8-week periods to determine the impact public market information has on marketing behavior and efficiency (Anderson, Ward, Koontz, Peel, & Trapp,

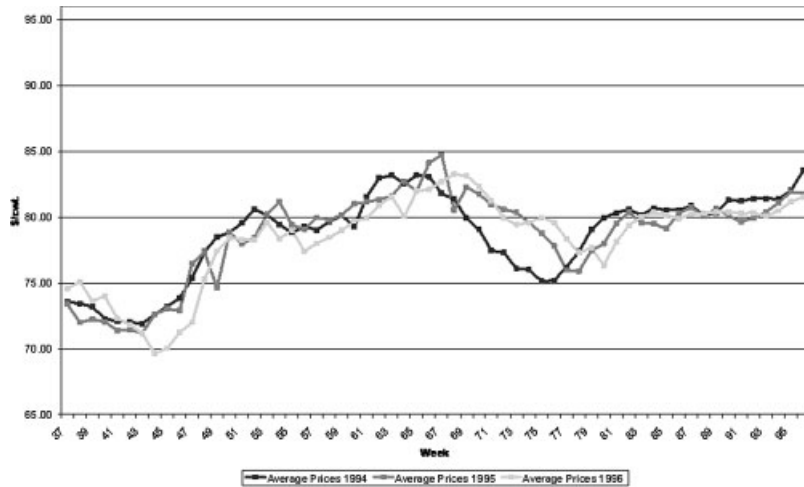


Figure 1 Weekly Average Fed Steer Prices for Semester-long Classes of the Experimental Market, 1994–1996.

1998). A cash reward system was incorporated into the experiment based on team profit performance.²

Data comprise 2,748 transactions from 74 trading periods (1994 semester), 3,530 transactions from 93 trading periods (1995), and 2,197 transactions from 60 trading periods (1996). Figure 1 illustrates how consistent market prices were over the three semesters, especially recognizing that two experiments were superimposed on market participants in two of the three semesters. This consistency is further evidenced by results of tests for significant differences in mean prices and purchases across years (Table 1). Thus, the game theory application uses data from one semester featuring a normal functioning fed cattle market, i.e., the FCMS market without an imposed experiment and two semesters with designed experiments. Differences in the data series provide the basis for comparing game theory application results across three market scenarios to test how market conditions and subsequent behavior affect results.

4. EMPIRICAL MODEL APPLICATION

Beefpacking at the industry level is modeled first in an attempt to discover evidence that firms behave in the hypothesized noncompetitive manner. The methodology focuses on firm processing margins similar to previous work (Richards & Patterson, 2003; Richards, Patterson, & Acharya, 2001; Schroeter & Azzam, 1991). However, firm-level data for this application facilitates making significant changes from previous models.

²In comparing prices and volumes across the three semester-long classes, there is no conclusive evidence that cash rewards contributed consistently and significantly to eliciting desired economic behavior by participants. No significant differences were found across packers and semesters for fed cattle purchases, i.e., both prices and volumes (Table 1 and Figure 1).

TABLE 1. Analysis of Variance Results for Procurement Prices and Volumes by Packer, 1994–1996

Player	1994 semester		1995 semester		1996 semester	
	Avg. price (variance)	Avg. volume (variance)	Avg. price (variance)	Avg. volume (variance)	Avg. price (variance)	Avg. volume (variance)
Packer 1	78.72 (11.22)	7.8 (6.0)	78.75 (12.84)	7.8 (2.2)	78.14 (13.92)	8.0 (4.2)
	<i>p</i> -value for price: 0.601		<i>p</i> -value for volume: 0.761			
Packer 2	78.28 (12.08)	8.1 (7.2)	78.34 (12.48)	8.3 (3.2)	78.10 (14.48)	8.7 (3.3)
	<i>p</i> -value for price: 0.935		<i>p</i> -value for volume: 0.381			
Packer 3	78.52 (11.30)	10.5 (6.8)	78.50 (12.41)	10.6 (7.1)	78.29 (12.35)	10.6 (2.6)
	<i>p</i> -value for price: 0.922		<i>p</i> -value for volume: 0.993			
Packer 4	78.75 (11.53)	12.0 (4.0)	78.68 (11.48)	11.6 (5.1)	78.66 (10.38)	11.9 (6.2)
	<i>p</i> -value for price: 0.989		<i>p</i> -value for volume: 0.548			
All Packers	78.67 (11.06)	36.6 (39.3)	78.66 (11.73)	36.8 (37.5)	78.43 (11.11)	36.7 (57.9)
	<i>p</i> -value for price: 0.906		<i>p</i> -value for volume: 0.983			

The objective function for packer i in the ordinary constituent game of the supergame is

$$\max \pi_i = pq_i - w_i(X, z)x_i - c(q_i) \quad (1)$$

where p and q are the price and quantity, respectively, of boxed beef sold in the wholesale market, $w_i(X, z)$ is the price of fed cattle, X is the total quantity of fed cattle available for sale, z is a vector of supply shifting exogenous variables, and $c(q_i)$ is the i th firm's cost as a function of the quantity of cattle processed. The input transformation function of the i th firm, which describes how fed cattle are processed into boxed beef, is

$$q_i = \gamma x_i \quad (2)$$

where γ is the dressing percentage. The processor's first-order condition for profit maximization is

$$\partial \pi_i / \partial x_i = \gamma (p c_q^i) w_i(X, z) - [(\partial w_i / \partial X)(\partial X / \partial x_i)] x_i = 0 \quad (3)$$

where c_q^i is the marginal processing cost of firm i .

The conjectural variation of a firm describes its response to changes in output by other firms and is denoted $\phi = dx_i / dx_j$. The conduct parameter is calculated as $\theta = 1 + \phi$ and must fall between zero (representing perfect competition) and two (representing monopsony or perfect collusion) because ϕ must lie between -1

and +1 (Binger & Hoffman, 1998; Richards, Patterson, & Acharya 2001). The intermediate case where $\theta = 1$ represents Cournot conduct.

The processing margin for packer i , having aggregated Equation 3 over all packers and assuming the conjectural variations are all the same, is

$$m_i = [p\gamma - w(X, z)] = c_q\gamma + \eta\theta X \tag{4}$$

where c_q is marginal cost and η is the inverse slope of the fed cattle supply function. Equation 4 is the optimal condition of input use for a firm with oligopsony power, i.e., marginal value product for each input is equal to its marginal outlay. The supply of cattle is exogenous in the FCMS, so no fed cattle supply function is estimated. Rather, a supply elasticity of 0.60 is assumed, partway between the Marsh (1982) estimate of 0.46 and the estimate of 0.67 found by Van Eenoo, Peterson, and Purcell (2000). A sensitivity analysis using Marsh’s and Van Eenoo, Peterson, and Purcell’s elasticities was carried out and results did not change in any meaningful way. The generalized Leontief (GL) cost function was used as it provides several favorable characteristics for the cost function and is of the form

$$c(q, w) = \lambda_1 q^2 w_1 + \lambda_2 q^2 w_2 + \lambda_3 q(w_1 w_2)^{1/2} \tag{5}$$

where w_1 = live cattle prices and w_2 = per-pen processing costs.

Richards, Patterson, and Acharya (2001) note that processors’ ability to exert market power is a function of capacity utilization. When supply is plentiful, prices are lower, and capacity utilization is higher, firms can be expected to engage in collusive behavior. Conversely, when supply is tight, with associated higher prices and lower capacity utilization, collusive behavior would be expected to decline. The conduct parameter measuring this behavior is specified as

$$\theta(k) = \delta_0 + \delta_1 k \tag{6}$$

where k represents industry plant capacity utilization.

5. ESTIMATION METHODOLOGY

A finite mixture estimation (FME) approach is used to estimate the percentage of collusive and reversionary periods for each year as well as the degree of market power that firms exert during these periods. This approach recognizes that packer margins during collusive and reversionary periods are drawn from different distributions characterized by distinct sets of parameters (Titterington, Smith, & Makov, 1985). The probability density function for the margin is then a weighted average of the densities for collusive and reversionary conduct, each of which possesses a mixing weight denoted τ_i for $i = 1, 2$ which are collusive and reversionary periods, respectively.

As a result, the margin Equation 4 can be written in regime-specific form, which is the processing margin with the GL cost function incorporated

$$m_c = \gamma\lambda_{c1}q^2 w_1 + \gamma\lambda_{c2}q^2 w_2 + \gamma\lambda_{c3}q(w_1 w_2)^{1/2} + \eta\theta_c X_c \tag{7}$$

during collusive periods, and

$$m_r = \gamma\lambda_{r1}q^2 w_1 + \gamma\lambda_{r2}q^2 w_2 + \gamma\lambda_{r3}q(w_1 w_2)^{1/2} + \eta\theta_r X_r$$

during reversionary periods. Note that Equation 6 is substituted into Equation 7 for θ during actual estimation. Because there is no obvious way to discern collusive from reversionary periods, an estimation technique is needed that determines data membership in one type of regime versus the other.

The expectation/maximization (EM) algorithm of Dempster, Laird, and Rubin (1977) is a latent variable method that may be used to assign periods into the collusive or reversionary regimes. As Richards, Patterson, and Acharya (2001) describe, the algorithm begins with the expectation step, during which segment weights are calculated. Then it assigns observations to one regime or the other depending upon its dominant posterior probability. In the maximization step, generalized least squares is used to calculate new parameter estimates for the margin equations. New aggregate shares for the regimes are then calculated, and a new iteration is begun. The process thus iterates between expectation and maximization until the value of the log-likelihood function changes with each iteration by less than some preselected amount, i.e., the convergence tolerance. This allows the final mixing weights and market conduct parameters for each regime to be observed.

The described procedure presupposes data are, in fact, generated by two separate regimes. In practice, it is necessary to test this assumption and Wolfe's likelihood ratio test is employed for this purpose. The calculated test statistic for each year is compared to critical values from the chi-square distribution, with a null hypothesis of a single model (no switching behavior) versus the alternative of a two-regime model.

6. EMPIRICAL RESULTS

Equation 7 was estimated for each of the three data sets via the EM algorithm using the IML procedure in SAS (SAS Institute, 1999). Table 2 shows the results of OLS estimation of the single-regime model as well as the results for the dual-regime model. The focus here is on the conduct parameter (θ). The null hypothesis of the single model for the 1994 semester was rejected, suggesting participants may have employed a trigger strategy. The estimate of the conduct parameter from the FME model (1.265) exceeds both the competitive and Cournot levels. Further, collusive behavior occurred 78.6% of the time. The reversionary parameter (0.045) is close to the perfectly competitive level. The industry conduct parameter thus indicates slightly more than the Cournot level of 1.0 for market conduct during collusive periods but close to the competitive level during reversionary periods.

Recall that the 1994 semester did not have an experiment imposed on the simulated market, thus arguably mimicking normal market behavior most closely. Results suggest that during normal market behavior, supply conditions provide an opportunity for firms to collude. This behavior is consistent with the hypothesized effects from higher supplies, lower prices, and higher capacity utilization rates.

For the 1995 semester, the null hypothesis of a single model could not be rejected at the 5% significance level, though the FME collusive conduct parameter (1.680) was significant and collusive behavior occurred 40.5% of the time. The reversionary regime conduct parameter from the OLS model (0.738) again approached the competitive level.

During the 1995 semester, a marketing agreement was imposed between the largest packer and the two largest cattle feeding firms. The marketing agreement resulted in fewer available cattle to satisfy the procurement needs of the three packers that were

TABLE 2. Ordinary Least Squares and Finite Mixture Estimation Results, 1994–1996

Parameter	Ordinary least squares						Finite mixture estimation					
	Single model			Reversionary regime			Collusive regime			Collusive regime		
	1994	1995	1996	1994	1995	1996	1994	1995	1996	1994	1995	1996
λ_1	-12.932 (-1.701)	-10.059 (-1.027)	-20.179 (-1.062)	-12.828 (-0.148)	16.435 (0.860)	-25.570 (-0.369)	-12.828 (-0.148)	16.435 (0.860)	-20.396** (-2.222)	-38.711** (-2.174)	-25.570 (-0.369)	-28.931** (-2.832)
λ_2	-0.034 (-0.378)	-0.140 (-1.165)	-0.126 (-0.499)	0.073 (0.101)	-0.164 (-0.657)	0.088 (0.125)	0.073 (0.101)	-0.164 (-0.657)	-0.095 (-0.099)	-0.264 (-1.144)	0.088 (0.125)	-0.456** (-3.944)
λ_3	3175.629 (0.969)	1394.821 (0.300)	5139.231 (0.672)	602.540 (0.020)	-6881.384 (-0.733)	1628.001 (0.062)	602.540 (0.020)	-6881.384 (-0.733)	5923.748 (1.584)	13053.516 (1.370)	1628.001 (0.062)	16762.444** (4.302)
δ_0	-2.669 (-1.542)	-4.784** (-2.550)	-2.574 (-0.910)	-1.086 (-0.055)	-5.961 (-1.496)	-1.934 (-0.186)	-1.086 (-0.055)	-5.961 (-1.496)	-4.629** (-2.277)	-3.263 (-1.118)	-1.934 (-0.186)	-2.924* (-1.913)
δ_1	4.110** (2.474)	5.888** (3.266)	3.703 (1.442)	1.218 (0.063)	6.656* (1.762)	2.138 (0.212)	1.218 (0.063)	6.656* (1.762)	6.350** (3.197)	5.269* (1.847)	2.138 (0.212)	5.219** (3.837)
θ	1.145* (1.730)	0.738 (0.898)	0.814 (1.129)	0.045 (0.227)	0.281 (0.303)	0.022 (0.054)	0.045 (0.227)	0.281 (0.303)	1.265 (1.022)	1.680** (2.284)	0.022 (0.054)	1.851* (1.822)
τ	—	—	—	0.214* (1.993)	0.600** (7.622)	0.594** (13.509)	0.214* (1.993)	0.600** (7.622)	0.786** (5.745)	0.400** (2.034)	0.594** (13.509)	0.406** (3.747)
R^2	0.201	0.445	0.138	—	—	—	—	—	—	—	—	—
Akaike Information Criterion	985.486	343.366	294.816	965.249	333.530	277.706	965.249	333.530	—	—	—	—

Note: *t*-ratios are given in parentheses. Double and single asterisks denote statistical significance at the 5% and 10% levels, respectively. Observations for each year are 2,748 (1994), 3,530 (1995), and 2,197 (1996).

not involved in the agreement. It is plausible that the marketing agreement gave the largest packer, the three packers not participating in the agreement, or all packers together an opportunity to behave collusively. Examining price behavior during the 1995 semester, higher prices were found but prices were much more variable during the marketing agreement periods (Ward et al., 1999). As a consequence, no conclusive evidence was found that the marketing agreement adversely affected buyer competition.

Results for the 1996 semester revealed similarities to the two previous semesters but also were unique. The single model hypothesis was rejected, again providing evidence of trigger strategy behavior, and the FME collusive conduct parameter was the highest of the three semesters (1.851), approaching the perfectly collusive mark of 2.0. Collusive behavior occurred 40.7% of the time and the reversionary parameter was small (0.022), as was the case in the previous two semesters.

During the 1996 semester, the amount of information available to the marketplace varied in a predesigned manner (Anderson et al., 1998). Limited information caused increased price variability and marketing inefficiencies. Cattle feeders were adversely affected by a lack of information, as they were unable to use market data to negotiate effectively with packing firms. Packers had more information about the wholesale market than did feeders, which may have enabled them to behave more collusively in light of less available public information regarding the entire market for cattle and beef. This explanation corroborates one reason for the existence of public information like that provided by USDA, as well as supports the Fama (1970) theory regarding information and efficient markets. Public information provides a sort of countervailing effect for producers in dealing with packers and other firms further up the supply chain and closer to final demand.

For all three semester-long periods, higher prices were associated with lower margins as seen in the parameter estimates for λ_1 (Table 2). For the 1996 semester, a significant inverse relationship was found between increased per pen processing costs (λ_2) and lower margins. As plant utilization increased in all three semesters, consistent with higher supplies and lower prices, collusive behavior increased, as indicated by δ_1 parameters in the collusive regimes.

7. SUMMARY AND CONCLUSIONS

The objective of this article was to develop and estimate a game theoretic model of industry conduct and supergame strategies in a dynamic oligopsony, i.e., beefpacking procurement. Data from the FCMS, an experimental market for fed cattle for three semester-long classes were used because real market data were not publicly available. A noncooperative, infinitely repeated game of beefpacker procurement was developed in which players were hypothesized to behave differently depending on fed cattle supply conditions and strategic considerations within the game. Player goals were assumed to be maximization of a discounted stream of processing profits.

The methodology was focused on firm processing margins similar to previous work. A finite mixture estimation (FME) approach was used to estimate the percentage of collusive and reversionary periods for each year as well as the degree of market power that firms exert during these periods. This approach recognizes that packer margins during collusive and reversionary periods are drawn from different distributions

characterized by distinct sets of parameters. An expectation/maximization (EM) algorithm was used to assign periods into a collusive or reversionary regime.

For two of the three semester-long periods, the single-regime model was rejected in favor of its dual-regime counterpart, an indication of trigger strategy behavior. The market conduct parameter was considerably higher for the collusive regime than the reversionary regime in each of the three semesters. Depending on the year, it approached perfectly competitive and perfectly collusive levels during reversionary and collusive regimes, respectively. Higher fed cattle prices were associated with lower packer margins as were higher processing costs. Higher plant utilization was associated with a higher level of collusive behavior, as hypothesized.

Market conditions imposed by experimenters in two of the three semesters may have contributed to estimation results. Imposing a marketing agreement between the largest packer and two feedlots may have altered the nature of the trigger strategy behavior and enhanced the ability of packers to behave collusively. Similarly, limiting the amount and type of public market information available to participants, may have given packers an edge because they had more information regarding the wholesale beef market. The asymmetric access to information may have created an opportunity for packers to behave collusively.

Application of a game theory approach to data from an experimental market is instructive because of the use of plant-specific, transaction-level data, given that such data for a real-world application are not publicly available. However, such data exist from special investigations conducted by Grain Inspection, Packers and Stockyards Administration (GIPSA). While the structure of the FCMS closely resembles that of the real fed cattle market, care must be exercised in inferring conclusions from the experimental market *directly* to those existing in the real-world market. If—given similar conditions—firms in the real fed cattle market behave in similar ways to firms in the experimental market, then the evidence discovered here supports claims of those cattle industry stakeholders who assert that packers extract excess rents from cattle feeders and in turn, from producers. *However, the issue cannot be resolved until regulatory agencies authorize estimation of similar game theory models with industry data and provide the necessary data they possess to academic researchers.*

This research provides evidence that a game theory approach applied to beefpacking industry conduct needs to be conducted with real-world data. However, results potentially may differ due to regional differences in buyer competitiveness, extent of precommitted supplies to packers, and seasonal or cyclical differences in cattle supply conditions.

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