Meatpacker Conduct in Fed Cattle Pricing:

Multiple-Market Oligopsony Power

by

Stephen R. Koontz and Philip Garcia

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The exercise of market power in multiple geographic fed cattle markets is measured with an econometric model which links behavior of the margin between boxed beef and regional fed cattle prices to an economic model of oligopsony conduct in multiple markets. A game theoretic economic model suggests that for market power to be exercised in a single market a discontinuous pricing strategy must be followed. Total market power is enhanced if meatpackers coordinate pricing across geographic markets. Tests reject independence of pricing conduct across geographic markets which suggests multiple-market market power is present. However, the magnitude of the market power is small and has decreased between the early and late 1980s.

Introduction

Producers, policy makers, regulatory agencies, and economists are concerned about the exercise of market power in geographically dispersed commodity markets (USGAO). Regional markets of interest include those for fed cattle, feeder cattle, hogs, and gasoline. Applied research addressing this issue has used various procedures to identify the existence and magnitude of market power. The classical approach for assessing market power in geographic markets involves estimating cross-market elasticities. Inelastic responses identify economic market boundaries and potentially isolated markets (Stigler and Sherwin). However, the quantity data needed to estimate demand, excess demand, supply, or excess supply models are generally not publicly available and are often proprietary. As a result, applied economists often examine regional price dynamics. The methods used vary from cross-market correlations to vector autoregression and error correction time series models (Goodwin and Schroeder (1990) and (1991); Hayenga and O'Brien; Schroeder and Goodwin; Slade; Uri, Howell, and Rifkin; Uri and Rifkin).

Much previous research suffers from several weaknesses that can lead to misleading conclusions about market power. It is unclear whether highly correlated or uncorrelated price movements between markets implies the presence or absence of market power. Price dynamics do not necessarily identify the boundaries of economic markets within geographic markets because transactions costs are not identified. Geographic markets with highly correlated prices are in the same economic market if the prices differ by levels greater than transactions costs between the markets. Geographic markets with uncorrelated prices also are in the same

economic market if the price levels differ by less than transactions costs. Economic market boundaries are not identified by price dynamics models, making questions of market power unclearly answered. Further, the co-movement in prices of geographic markets may be due to general supply and demand factors influencing both markets. Agricultural markets often exhibit seasonal price patterns. This variation will result in strong cross-market price correlations yet the geographic markets may be economically separate. Finally, the root of the problem with price dynamics studies is that these empirical models are not derived explicitly from an economic model of oligopoly or oligopsony behavior. The models provide indirect measures of conduct based on economic models of competitive or monopoly/monopsony markets.

This paper presents a direct measure of the competitiveness of pricing conduct by meatpackers across multiple geographic fed cattle markets. Unlike studies based on price dynamics, this measure is not affected by transactions costs. Further, the measure is derived from an economic model of oligopsony pricing conduct.

Single-Market Model

This section summarizes the single-market model of oligopsony power from Koontz, Garcia, and Hudson which is generalized to a multiple-market model. The model is of pricing by meatpackers in the purchase of fed cattle. The economic model is a noncooperative pricing game. Noncooperative refers to the structure of player interaction. Meatpackers cannot form enforceable agreements, so if market power is exercised it must be done tacitly through self-enforcing agreements.

A meatpacker produces meat (y) from fed cattle (x) and other inputs (v). A production process with fixed proportions between fed cattle and other inputs is assumed. The proportion of live animal converted to meat is $1/k$. Profits of the ith meatpacker are

$$(1) \qquad \pi_i(p_t^i, p_t^{-i}, z_t) = (r_t - p_t^i k) \, y_t^i(p_t^i, p_t^{-i}, W_t, \xi_t) - c_i(z_t)$$

where t is time, p^i is the cattle price paid by the ith firm, p^{-i} is a vector of cattle prices paid by all other firms, r is the meat price, and z is a vector of other input prices. Profits equal the margin multiplied by volume, less other input costs. The volume of cattle processed is influenced by the price the ith firm offers for cattle, prices offered by other meatpackers, exogenous variables W, and random variations ξ.

In the repeated game, the profits of the ith firm are the sum of current and discounted expected future profits

$$(2) \qquad V_i(s_t) = E[\sum_{t=0}^{\infty} \delta^t \pi_i(s_t^i, s_t^i)] \quad i = 1, \ldots, n \text{ and } 0 < \delta < 1,$$

where profits depend on a firm's pricing strategy s_t^i and strategies s_t^{-i} of all other firms. The discount rate is δ and expectations are taken over strategies. Nash equilibrium identifies

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strategies where each firm is not able to improve profits by changing strategy unilaterally. It is the only reasonable equilibrium concept for a noncooperative game where players make simultaneous decisions (Friedman).

In a single-period game, the Nash strategy is for all players to price so that marginal costs equal marginal revenues (Friedman). If the cattle price offered (i.e., marginal cost) is less than marginal revenue from meat sold, there is an incentive for each packer to offer a higher price, secure a larger market share of the cattle procured, and sell more meat. However, when all packers respond to this incentive, cattle prices are bid up to marginal revenue and there are no pure profits earned nor market power exercised.

In a multiple-period game, Nash equilibrium can support strategies where market power is exercised. As in the single-period game, individual firms have an incentive to improve profits by increasing cattle price offers. However, a punishment phase can deter cheating on the tacit agreement. A punishment strategy is as follows: all firms price at cooperative level p' if, in the last period, all other firms priced at the cooperative level. However, if one firm prices at p^* > p' then all firms revert to Nash behavior p". For collusive pricing to be a Nash equilibrium strategy, returns from cheating followed by single-period Nash behavior must be less than incentive to cooperate, or

(3) $V_i(p') > \pi_i(p^*) + \delta V_i(p'')$ for all firms

Equation (3) is the incentive constraint.

Green and Porter generalize this game recognizing that each firm may not observe the actions of other firms perfectly. Collusive equilibria remain possible but the punishment strategy must be modified. Because noncooperative behavior can occur accidently from random price variations, the strategy must be more forgiving. With imperfect information, meatpackers maximize value function (2) subject to a threshold strategy

(4) $s_t^i = \begin{cases} p' & \text{if } \mu < m_{t-1} \\ p'' & \text{if } \mu \geq m_{t-1} \end{cases}$ in the last T-1 periods

where μ is a threshold margin level, p' and p" are cooperative and noncooperative price levels, and m_{t-1} is the margin between meat price and an observable cattle price during some previous period. If the margin in the previous period is greater than threshold level μ, the firm offers cooperative price p'. However, if the margin in the previous T-1 periods is less than the threshold level, the firm offers noncooperative price p". Like the punishment strategy, cooperation is enforced through threat of temporary high prices and low profits.

Substituting the threshold strategy (4) into the value function (2) yields the recursive equation (5) summarizing the multiple-period optimization problem. For a firm initially in the cooperative phase, the value function is

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$$V_i(p') = \pi_i(p') + Pr\{\mu < m_t\} \, \delta V_i(p')$$

(5)
$$+ Pr\{\mu \geq m_t\} \, [\sum_{t=1}^{T-1} \delta^t \pi_i(p'') + \delta^T V_i(p')].$$

The incentive constraint for the threshold margin strategy is

(6) $$V_i(p') > \pi_i(p^*) + \sum_{t=1}^{T-1} \delta^t \pi_i(P') + \delta^T V_i(p')$$

where $p^* > p'$ is the price the cheating firm pays. Equation (6) states collusive profits are greater than the one-period gain from cheating plus T-1 periods of Nash profits. The incentive constraint must hold for threshold margin pricing to be an equilibrium strategy and for market power to be exercised.

If threshold pricing is an equilibrium strategy, players do not willingly cheat of the tacit agreement. However, the random element in prices will cause margins to periodically cross the threshold level. For the strategy to be credible, the players must then revert to pricing at single-period Nash levels. Players may also revert to Nash pricing when they tacitly renegotiate the level of market power exercised in the strategy. Oligopsony behavior is not on the continuum between perfect competition and monopsony. Rather, actions are discontinuous: Nash during noncooperative phases and bounded away from monopsony solutions during cooperative phases (Porter 1983a). This implies a discontinuous pattern in meatpacker margins will be observed if threshold pricing is followed.

Multiple-Market Model

Punishment strategies have been used to study multiple-market conduct (Bernheim and Whinston; Gelfand and Spiller). The underlying notion is that firms in an industry often encounter each other in multiple markets. Rather than treat each market separately, firms can treat conduct of other firms in all relevant markets, as a single type of conduct.

The optimization problem of the firm in a multiple market setting is similar to the single market problem. Firms maximize the expected value of the sum of discounted future profits across K markets

(7) $$V_i(s_t) = \sum_{k=1}^{K} V_{ik}(s_t) = E[\sum_{k=1}^{K} \sum_{t=0}^{\infty} \delta^t \pi_{ik}(s_t^i, s_t^{-i})]$$

where s_t^i and s_t^{-i} denote vectors of strategies across the K relevant markets, through choice of threshold margin strategies

$$
(8) \quad s_t^i = \begin{cases} p' & \text{if } \mu < m_{t-1} \quad \text{in all } K \text{ markets} \\ p'' & \text{if } \mu \geq m_{t-1} \quad \text{in any of the } K \text{ markets for the last } T-1 \text{ periods} \end{cases}
$$

where μ is a vector threshold margin levels and m_{t-1} is the vector of margins some previous period. If any firm fails to conform with the collusive agreement, this causes noncooperative behavior by the other firms in all relevant markets. The firm's strategies incorporate a threshold strategy with respect to margins within all K of the relevant geographic markets.

The value function of a firm in multiple markets is

$$
(9) \quad V_i(p') = \sum_{k=1}^{K} V_{ik}(s_t) = \sum_{k=1}^{K} \{ \pi_{ik}(p') + \Pr\{\mu < m_t\} \, \delta V_{ik}(p') \\
+ \Pr\{\mu \geq m_t\} \, [\sum_{t=1}^{T-1} \delta^t \pi_{ik}(p'') + \delta^T V_{ik}(p')]\}
$$

where the inequality $\mu \geq m_t$ is violated if any of the vector elements violates the inequality. The incentive constraint for the threshold strategy is pooled across markets

$$
(10) \quad \sum_{k=1}^{K} V_{ik}(p') > \sum_{k=1}^{K} [\pi_{ik}(p^*) + \sum_{t=1}^{T-1} \delta^t \pi_{ik}(p'') + \delta^T V_{ik}(p')].
$$

The incentive constraint must hold for a multiple-market threshold margin pricing to be an equilibrium strategy and for market power to be exercised across multiple markets.

The pooled incentive constraint is the key to market power in multiple markets. Multiple-market contact cannot reduce the ability of firms to collude (Bernheim and Whinston). Firms can always treat each market in isolation so the set of equilibrium strategies cannot be reduced. The pooling can only relax binding incentive contracts for individual markets and increase collusive profits. However, if the benefits (i.e., the collusive profits) and the costs (i.e., the punishments) of collusion increase proportionally they will balance each other in the multiple market setting. Bernheim and Whinston show that in spatially separate markets with positive transportation costs and when firms have increasing returns to scale, the benefits are greater than the costs. These conditions describe the meatpacking industry (Connor). Punishments are the most costly to a deviating firm in terms of the reduction of its profits. The threat of severe punishments supports very collusive levels of profits in the cooperative periods. By cooperating across markets, the industry members can enhance their profits. However, there are limits to collusion. The more markets that are considered, the more costly it is for firms to coordinate pricing. With more markets and players, the collusive equilibrium is less likely to be supported because the tacit communication between players must increase. If the cost of managing the coordination is excessive, meatpackers may treat each region as independent. Thus, identifying multiple region market power becomes an empirical exercise.

The single-market model implies the exercise of market power in individual markets will result in a discontinuous pattern in margins or prices for those markets. The multiple-market model implies the exercise of market power across geographic markets will result in the discontinuous pattern having parallel dynamics across the relevant markets. In multiple markets which are coordinated, there should be a high degree of correlation between movement of the markets between the cooperative and noncooperative phases in the various marketplaces. Finding this correlation in multiple-market price dynamics implies cooperation between players within and across markets. The extent of the cooperation can be measured by the strength of this correlation.

Methods

The econometric model for pricing conduct in a single market is summarized in this section. The model provides information about whether or not each single market is in the cooperative or noncooperative phase. We then measure the co-movement of this probability of cooperation across geographic markets to assess the coordination of market power in multiple markets.

The econometric model is derived from first-order condition for a profit maximizing firm. Maximizing (1) through choice of price results in the following

$$(11) \qquad \partial \pi_i / \partial p_i = (r - p_i k) \ [\partial y_i / \partial p_i + \sum_{j \neq i} (\partial y_i / \partial p_j)(\partial p_j / \partial p_i)] - k y_i = 0$$

where p_j denotes the price offered by the jth firm, $j \neq i$. The procurement response to the cattle price is a structural parameter

$$(12) \qquad \partial y_i / \partial p_i = \gamma \text{ and } \partial y_i / \partial p_j = -\gamma / (n-1) \text{ where } j \neq i \text{ and } j = 1, ..., n.$$

The sum of conjectures has structure from the economic model. In noncooperative periods the conjecture is zero and in cooperative periods it is positive

$$(13) \qquad [1 / (n-1)] \sum_{j \neq i} (\partial p_j / \partial p_i) = \beta_i = \begin{cases} \beta_{i0} > 0 & \text{during the cooperative phase} \\ 0 & \text{during the noncooperative phase.} \end{cases}$$

The conjecture measures the average change in cattle price offered by other firms as meatpackers switch between phases.

Because only regional price data are available, the first-order condition is aggregated over n firms, yielding an expression in market variables: p_t is average regional cattle price, β measures the average conjecture across firms (Bresnahan), and the margin $(r_t - p_t k)$ is denoted as m_t. Also, because only price data are available, aggregate quantities (y_t) are captured through

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$$(14) \qquad y_t = W_t \eta + \xi_t$$

where W_t is the tth row of an exogenous variable matrix, η are parameters, and ξ_t an error term. Exogenous variables include current feeder cattle prices, corn prices, interest rates, and temporal variables. Daily regional fed cattle supply is not a function of fed cattle price (Reutlinger; Arzac and Wilkinson). Rather, prices divide the fixed number of animals between meatpackers.

Substituting equations (12), (13), and (14) into (11) yields an equation where margins are modelled as a function of factors capturing variations in supply and the state of cooperation between meatpackers. The cooperative/noncooperative behavior is represented by a proportional increase in the mean and variance of the margin equation

$$(15) \qquad m_t = \begin{cases} W_t \alpha + \varepsilon_{1t} & \text{if } m_t \text{ is cooperative and} \\ W_t \alpha \phi + \varepsilon_{2t} & \text{if } m_t \text{ is noncooperative} \end{cases}$$

where $\varepsilon_{2t} = \phi \varepsilon_{1t}$. Assuming $\varepsilon_{1t} \sim N(0, \sigma^2)$, results in $\varepsilon_{2t} \sim N(0, \phi^2 \sigma^2)$. The conjecture is identified, $\beta_0 = (1 - \phi)$.

If the sequence regime changes were known, an indicator function could be defined

$$(16) \qquad I_t = \begin{cases} 1 & \text{if } m_t \text{ is in the cooperative regime} \\ 0 & \text{if } m_t \text{ is in the noncooperative regime,} \end{cases}$$

and estimation of a switching regression would be conditioned on the regime. In this case, the density for observation m_t given the data and I_t is

$$(17) \qquad \begin{aligned} h(m_t \mid W_t, I_t) &= I_t / \sigma \sqrt{2\pi} \, \exp\{-(m_t - W_t \alpha)^2 / 2\sigma^2\} \\ &\quad + (1 - I_t) / \phi \sigma \sqrt{2\pi} \, \exp\{-(m_t - W_t \alpha \phi)^2 / 2\phi^2 \sigma^2\} \end{aligned}$$

and estimation of the parameters in the density is straightforward. Since the sequence of switches is not known, a process to classify each observation in the cooperative or noncooperative phase must be specified and the density modified. We use a Bernoulli process, which has been used in all previous applications of this type of model (e.g., Porter 1983b).[1] Under the Bernoulli approximation, cooperative and noncooperative phases occur with probabilities λ and $(1-\lambda)$.

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[1] The economic model suggests a T-Markov process. However, estimating a T-Markov switching regression has limitations rendering it infeasible (Green and Porter). While the T-Markov is useful to derive analytical results for the economic model, its use in estimation would fix the noncooperative period length. In practice, the length of these periods may be flexible; actions within the strategy may vary (Porter 1985). Also, variations on collusive strategies may not be T-Markov (Abreu et al.). The Bernoulli process is flexible enough to approximate a T-Markov process and may be robust to alternative processes.

In the Bernoulli model, the density for observation m_t is

$$
(18) \quad h(m_t \mid W_t) = \lambda / \sigma \sqrt{2\pi} \, \exp\{-(m_t - W_t\alpha)^2/2\sigma^2\}
$$
$$
+ (1 - \lambda)/\phi\sigma\sqrt{2\pi} \, \exp\{-(m_t - W_t\alpha\phi)^2/2\phi^2\sigma^2\}.
$$

The log-likelihood function satisfies regularity conditions for consistency and asymptotic normality of maximum likelihood estimates, which are denoted as $\theta^* = (\alpha^* \, \sigma^* \, \phi^* \, \lambda^*)$.

The switching regression can be used to measure the probability that each observation is in the cooperative or noncooperative regime. Following Porter (1983b) and Kiefer, regime classification probabilities are calculated using the maximum likelihood estimates and Bayes rule

$$
(19) \quad w_t^* = \frac{\lambda^* \, h(m_t \mid W_t, \alpha^*, \sigma^*, I_t = 1)}{\lambda^* \, h(m_t \mid W_t, \alpha^*, \sigma^*, I_t = 1) + (1 - \lambda^*) \, h(m_t \mid W_t, \alpha^*, \phi^*, \sigma^*, I_t = 0)}
$$

where w_t^* identifies the probability that each observation is in the cooperative regime. The w_t^* provide estimates of I_t. From Lee and Porter,

$$
(20) \quad I_t^* = \begin{cases} 1 & \text{if } w_t^* > 0.5 \\ 0 & \text{if } w_t^* \leq 0.5. \end{cases}
$$

The w_t^* and I_t^* series provide complementary information about the exercise of market power in multiple markets. The co-movements in I_t^* across geographic markets provides direct information about the parallel changes in the state of cooperation across geographic markets and the exercise of multiple-market market power through multiple-market threshold pricing. The I_t^* series are estimates of actual behavior. The co-movements in w_t^* across geographic markets provides the same information in a different random variable structure. The co-movements in w_t^* across geographic markets provides information about the parallel changes in the probability of cooperation. The dynamics in the w_t^* series provides information about the environment of cooperation across markets. The structure of the two random variables suggest different methods of analysis.

Information from contingency tables are used to test the pair-wise independence of the I_t series. 2x2 contingency tables are structured as follows

		I_{2t}		
		Cooperative	Noncooperative	Total
I_{1t}	Cooperative	p_{cc}	p_{cn}	p_{c+}
	Noncooperative	p_{nc}	p_{nn}	p_{n+}
	Total	p_{+c}	p_{+n}	

where I_{1t}^* and I_{2t}^* are the estimates of the state of cooperation in geographic markets 1 and 2, and p_{ij} are the probabilities of the various combination of states. In the absence of multiple-market market power, the movements of the I_{kt}^* series between cooperative and noncooperative states are independent. The null hypothesis of independence is

$$H_0: \; p_{ij} = p_{i+} \cdot p_{+j} \quad \text{for } i = c, n \text{ and } j = c, n.$$

For example, if the state of cooperation in the two markets are independent, the probability that both markets are in the noncooperative state (p_{nn}) is equivalent to the probability that market 1 is in the noncooperative state (p_{n+}) multiplied by the probability that market 2 is in the noncooperative state (p_{+n}). Rejecting the null hypothesis for one combination of i and j implies rejection of the hypothesis for all combinations. Thus, there is one test statistic. The strength of the multiple-market cooperation is measured by the probability that both markets are in the cooperative state (p_{cc}).

The probability that both markets are in the cooperative state is then used as the dependent variable in a regression model. The model explains the level of the probability of cooperation as a function of distance between the two regions, the total number of meatpacking firms in both regions, the number of meatpacking firms which are common to both regions, the average number of cattle slaughtered in the two regions, the average four-firm concentration ratio for the two regions, and a dummy variable for whether or not either market is a terminal cash market. The markets are classified into one of three regions and a same-region dummy variable is also included in the model. The three regions are the corn belt, the central plains, and the southern plains. Illinois, Iowa, E. Nebraska, and the terminal markets are classified in the corn belt region. Colorado and W. Nebraska are in the central plains region, and E. Kansas, W. Kansas, and Texas are in the southern plains region. The firm number and composition explanatory variables are similar to those used by Porter (1985). The greater the total number of meatpackers or the number of meatpacking firms, the less likely tacit collusion will be an equilibrium pricing strategy. However, the greater the number of meatpackers which are common between two regions, the more likely tacit collusion will be an equilibrium pricing strategy. Further, the greater the distance between two regions, the less likely the meatpackers in each region can treat the two regions as one market. The same-region dummy variable is an alternative measure of distance between markets. Traditional industrial organization theory suggests the four-firm concentration ratio should be positively related to exercise of market power. These hypotheses are tested. The potential affect of a terminal market and market volume on the probability of cooperation is not known *a priori*.

Information from Granger causality tests are used to measure the pair-wise dynamic interaction of the w_{kt}^* series. The variables w_{1t}^* and w_{2t}^* are rewritten as x_t and y_t. All series are stationary or exhibit a deterministic trend. Standard Granger-type models are used

$$(21) \qquad x_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, x_{t-i} + \sum_{j=1}^{q} \gamma_j y_{t-j} + u_{1t} \qquad \text{var}(u_{1t}) = \sigma_1$$

$$(22) \qquad y_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, y_{t-i} + \sum_{j=1}^{q} \delta_j x_{t-j} + u_{2t} \qquad \text{var}(u_{2t}) = \sigma_2$$

where the trend variable is omitted for simplicity. Akaike's Information Criterion is used to determine the optimal lag lengths for each variable in the two models. F-tests are used to examine the significance of past values of the probability of cooperation in various other markets on the current probability of cooperation of each individual market.

Pure autoregressive models are also estimated. The error variance of the x_t autoregressive model is denoted ω_1 and the error variance of the y_t autoregressive model is denoted ω_2. Geweke defines measures of the linear association between two variables as

$$(23) \qquad P_{x \to y} = \ln(\omega_1 / \sigma_1) \quad \text{and} \quad P_{y \to x} = \ln(\omega_2 / \sigma_2).$$

The expressions measure the strength of the linear causality from x to y and from y to x. In the case of feedback, where causality occurs from x to y and from y to x, the strength measure can be used to determine which causal flow is largest. Symmetry of the causal flow can be tested with the following statistic

$$(24) \qquad \delta = [T \cdot P_{x \to y} - (d - 1)/3]^{1/2} - [T \cdot P_{y \to x} - (d - 1)/3]^{1/2}$$

where T is the number of observations and d is the dimension of the model (i.e., two). The statistic approximates a normal(0,2) under the null hypothesis of symmetric causality (Geweke).

In the analysis that follows, we report the causal flow results between pairs of markets using the small sample F-tests of causality, and where causality occurs in both directions the test of symmetry is reported to identify any dominant market. Thus, analysis of the co-movement of the I_t^* series across markets reveals the actual exercise of multiple-market market power. While, analysis of the dynamic interaction of the w_t^* series across markets reveals which regional markets lead the U.S. fed cattle marketplace in movements between cooperative and noncooperative pricing phases.

Results

The daily fed cattle price data are from eight USDA AMS direct feedlot-to-meatpacker trade regions and two terminal markets. The direct markets are: Illinois, Iowa and Southern Minnesota, Eastern Nebraska, Eastern Kansas, Western Kansas, Colorado, the region including Western Nebraska, Southwestern South Dakota and Wyoming, and the region including the Texas and Oklahoma panhandles and Northeastern New Mexico. The terminal markets are Omaha NE, and Sioux City IA. A large portion of total U.S. fed cattle sales occur in these eight regions. The USDA daily boxed beef cutout value series for choice 550-to-700 pound carcasses is the meat price used to calculate the margin series.

A potential difficulty with our model is that the inference about market power requires identifying a component in the margin equation error term. The difficulty is that shocks other than changes in conduct may influence margin levels. Hence, it is important to apply this model to data from time periods that are structurally stable in terms of the underlying industry cost and supply functions (Green and Porter). Examining the industry structure between 1980 and 1992

reveals two periods of relative stability: June 1980 through September 1982, and July 1984 through July 1986 (Ward; Meat Industry Magazine). These two periods are used in the analysis.

Koontz, Garcia, and Hudson present the results of the single market models. In summary, they find market power persists in all regional fed cattle markets. However, the extend of the market power is relatively small in dollar per animal losses and that less market power is exercised in the second period. Summary statistics of the probability of cooperation (w_t^*) and the state of cooperation estimate (I_t^*) series are presented in Table 1. The results clearly shown a higher incidence of cooperation during the first time period and thus a higher degree of market power being exercised.

The probability that a pair of the geographic markets are both in a cooperative state are presented in Table 2. Estimates of the state of cooperation are aggregated. This is done assuming players in the different geographic markets need time to observe and react to prices in other markets. The results from aggregating I_t^* over the current and previous four business days. Results show the linkages between pair of markets over a week. Independence of the pairs of markets in the movement between cooperative and noncooperative states is overwhelmingly rejected. Most of the tests are significant at the 1% level and all are significant at the 5% level with four exceptions. In the first period, independence is rejected at the 10% level between E. Nebraska and Illinois, and between E. Nebraska and Colorado. In the second period, independence is not rejected between Colorado and Texas, and between Illinois and Sioux City. Fisher's Exact Test is used because of the small number of observations in some contingency table cells. Multiple-market market power is exercised across geographic fed cattle markets. However, as with the single market model results, the extent of the market power is small and much lower in the second time period. The Illinois, Iowa, E. Nebraska, Omaha, and Sioux City markets interact the most closely. The multiple market interaction of Colorado with other geographic markets is the smallest. The remaining western plains states markets exhibit intermediate levels of market power.

Models summarizing the probability of cooperation results in Table 2 are presented in Table 3. In the first period examined, the same-region dummy variable is significant at the 6.5% level and the four-firm concentration ratio is significant at the 2.5% level.[2] If a pair of markets are in the same geographic region (i.e., corn belt, central plains, and southern plains), the markets exhibit a 16% higher probability of jointly being in the cooperative phase. This result suggests regional market boundaries are consistent with this three region classification. A 10% increase in the average four-firm concentration ratio of two regions leads to a 8.9% decline in the probability that the pair of markets are jointly in the cooperative phase. This is opposite of what is suggested by traditional industrial organization theory but may reflect that the same firms are not present in regions with high concentration ratios. Further, the meatpacking industry experienced excess capacity during the entire mid-to-late 1980s, and excess capacity may have been most severe in regions with high concentration. Thus, pricing was the

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[2] Because of the dependent variable is not distributed normal, parameters and standard errors where examined through the bootstrap method. The bootstrap results were not different from the least squares results.

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most competitive in high concentration regions and an unexpected sign is found in the regression results. Variables capturing the number of firms and the number of common to both regions are both insignificant. Although, these measures are to a degree correlated with the same-region dummy variable and the coefficients do have the expected sign. For the second period, the number of common firms variable is significant at the 5.4% level and the terminal market dummy variable is significant at the 3.1% level. If a pair of markets has one more firm in common than another pair with like characteristics, then the markets exhibit a 2.3% higher probability of jointly being in the cooperative phase. This result is consistent with the economic model. If one of the two markets in a pair is a terminal market, the pair are 9.8% more likely to jointly be in the cooperative phase. This last result suggests that the presence of terminal markets, an alternative marketing institution, does not mitigate the exercise of market power or enhance competition in fed cattle markets. In fact, the opposite may be occurring due to the thinness of terminal markets.

Tables 4 and 5 present the results from the Granger causality tests between the different w_t^* series. Arrows denote significant casual flows based on F-tests. The statistic reported under the arrows is the test for symmetric causal flows. The first period results are in Table 4 and the second period are in Table 5. The results suggest there is considerable interaction between the w_t^* series across geographic markets. There is no one market which leads the exercise of multiple-market market power. However, there are groups of markets which lead and interact in this behavior, there are markets which follow the leading markets, and there are pairs of markets which do not interact in this cooperative behavior.

In the first period, Illinois and Iowa are follower markets. Colorado is a leader market, but the extent of market power exercised between Colorado and other markets is small. There is much feedback between E. Nebraska, W. Nebraska, E. Kansas, W. Kansas, Texas, and the terminal markets, and much of the feedback is symmetric. Only the feedback between E. Nebraska and Texas is asymmetric with E. Nebraska being the leading market. There are also a few markets which do not interact. E. Kansas and Iowa, Colorado and W. Kansas, W. Kansas and the terminal markets have no significant causal flows. The results suggest pricing behavior in Nebraska and Kansas leads the movement of the regional markets to the cooperative phase during the 5/80 to 9/82 time period. Further, the amount of causality and feedback suggests the extent of fed cattle market boundaries was large during this time period. Causal flows and feedback are highest between markets within the three regions. However, causality is present between markets across the three regions.

In the second period, there is much less feedback. Identifying leader and follower markets is easier. There are also many more cases where markets are not interacting. Iowa, E. Kansas, and W. Kansas are leader markets. Although, W. Kansas does not interact with several markets. Illinois, E. Nebraska, and W. Nebraska are follower markets. Colorado and the terminal markets are both leaders and followers. The probability of cooperation is Texas does not interact with any markets with the exception of the two Kansas markets. Texas is the most independent market and W. Kansas is the second most independent. The results suggest pricing behavior in Iowa and Kansas leads the movement of the regional markets to the cooperative phase during the 7/84 to 7/86 time period. However, the exercise of multiple-market market power is much less prevalent during this time period which suggests the extent

of fed cattle market boundaries was small.[3] The absence of causality suggests meatpackers treat pricing within regional markets are independent decisions. Thus, little multiple-market market power is being exercised.

Conclusions

We have developed a noncooperative game-theoretic model of meatpacker pricing conduct across geographic markets. The economic model suggests exercise of market power results in a specific type of price behavior. We test for and find this price behavior in geographic fed cattle markets during a time period encompassing 5/80 to 9/82 and separately for the time period 7/84 to 7/86. The geographic fed cattle markets examined include the major direct and terminal markets in the corn belt, central plains, and southern plains states.

The economic model suggests that exercise of market power purchasing fed cattle requires meatpackers to follow a two phase pricing strategy: low prices are paid during cooperative phases and high prices are paid during noncooperative phases (high and low relative to the value of boxed beef). This strategy can be extended to a multiple market setting: low prices are paid in all relevant markets during cooperative phases and high prices are paid in all relevant markets during noncooperative phases. Meatpacker profits are enhanced during cooperative phases above the more competitive levels experienced during noncooperative phases.

The discontinuous pattern is found in the behavior of fed cattle prices for each of the regions examined and the discontinuous patterns are not independent across regions. This implies the exercise of market power is coordinated across regional markets or that the geographic regions underlying the reported prices are part of a larger economic market for fed cattle. There is evidence that the corn belt regional markets (Illinois, Iowa, E. Nebraska, Omaha NE, and Sioux City IA), the central plains markets (W. Nebraska and Colorado), and the southern plains markets (E. Kansas, W. Kansas, and Texas) each constitute an economic market. However, Colorado and Texas are largely independent. There is also evidence that the more meatpackers that are common within two geographic regions, the more market power that is exercised. However, the overall magnitude of the multiple-market market power is small particularly in the second period.

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[3] Interestingly, the economic market boundaries appear to be the smallest when smallest amount of multiple-market market power is being exercised. This is the time when exercise of market power would be most profitable.

Table 1. Summary Statistics of the Probabilities that the Various Regional Markets are in the Cooperative Phase for the Period from 5/80 to 9/82 and the Period 7/84 to 7/86.

First Period	Obs	Mean	Std Dev	Min	Max	% Coop	% Noncoop
Illinois	608	0.4690	0.1802	0.2162	0.9995	0.2928	0.7072
Iowa	608	0.4337	0.1815	0.1693	0.9993	0.2303	0.7697
E. Nebraska	608	0.5776	0.1819	0.3208	0.9999	0.4967	0.5033
W. Nebraska	608	0.2705	0.2249	0.0608	0.9999	0.1349	0.8651
E. Kansas	608	0.2989	0.1926	0.1192	0.9987	0.1250	0.8750
W. Kansas	608	0.1978	0.1971	0.0436	1.0000	0.0806	0.9194
Colorado	608	0.0945	0.1537	0.0099	0.9999	0.0362	0.9638
Texas	608	0.2587	0.1884	0.0746	0.9955	0.0970	0.9030
Omaha, NE	608	0.2948	0.1804	0.1316	0.9889	0.1168	0.8832
Sioux City, IA	608	0.3614	0.2131	0.1127	0.9996	0.1826	0.8174

Second Period	Obs	Mean	Std Dev	Min	Max	% Coop	%Noncoop
Illinois	526	0.0237	0.0627	0.0045	0.9607	0.0038	0.9962
Iowa	526	0.0643	0.0956	0.0252	0.9762	0.0114	0.9886
E. Nebraska	526	0.0593	0.964	0.0207	0.9800	0.0114	0.9886
W. Nebraska	526	0.0465	0.1211	0.0043	0.9995	0.0152	0.9848
E. Kansas	526	0.1670	0.1910	0.0049	1.0000	0.0608	0.9392
W. Kansas	526	0.1039	0.1439	0.0059	1.0000	0.0304	0.9696
Colorado	526	0.1470	0.1075	0.0529	0.9473	0.0209	0.9791
Texas	526	0.2243	0.1429	0.1174	0.9974	0.0513	0.9487
Omaha, NE	526	0.1782	0.1721	0.0376	0.9985	0.0589	0.9411
Sioux City, IA	526	0.4050	0.2397	0.1259	1.0000	0.2338	0.7662

Table 2. Probability that the Market on the Vertical Axis is in the Cooperative Phase given the Market on the Horizontal Axis is in the Cooperative Phase during the Current or Previous Four Business Days.

First Period / Second Period	IA	E. NE	W. NE	E. KS	W. KS	CO	TX	Omaha	Sioux
Illinois	0.6250 0.0114	0.7928 0.0095	0.4605 0.0114	0.3931 0.0114	0.2993 0.0114	0.1563 0.0	0.3618 0.0114	0.3947 0.0114	0.5674 0.0114
Iowa		0.6760 0.0304	0.4227 0.0285	0.3799 0.0494	0.2780 0.0494	0.1513 0.0190	0.3306 0.0342	0.3586 0.0494	0.5016 0.0494
E. Nebraska			0.4934 0.0342	0.4276 0.0551	0.3273 0.0399	0.1612 0.0190	0.3849 0.0418	0.4145 0.0494	0.6053 0.0570
W. Nebraska				0.3438 0.0551	0.2368 0.0475	0.1414 0.0171	0.2911 0.0380	0.3207 0.0532	0.4342 0.0646
E. Kansas					0.2615 0.1046	0.1398 0.0703	0.2862 0.1141	0.2664 0.1483	0.3454 0.2471
W. Kansas						0.1201 0.0361	0.2368 0.0951	0.2204 0.1236	0.2714 0.1426
Colorado							0.1414 0.0247	0.1316 0.0760	0.1414 0.0932
Texas								0.2484 0.0989	0.3092 0.2053
Omaha, NE									0.3635 0.2414

Table 3. Regression Model Results where the Probability that Various Market Pairs are in the Cooperative Phase is Explained as a Function Regional Market Characteristics.

Variable	First Period Model		Second Period Model	
	Coefficient	Standard Error	Coefficient	Standard Error
Distance	-2.1283	2.8150	-0.2989	1.0190
Same-Region Dummy	15.9620*	8.3760	-1.1513	2.4520
Volume	0.0898	0.0242	0.5585	0.6995
Four Firm Concentration Ratio	-0.8623**	0.3693	0.1789	0.1798
Number of Firms	-0.3533	1.9810	0.3879	0.7423
Number of Common Firms	4.1297	2.9780	2.2909*	1.1490
Terminal Market Dummy	-2.3670	12.7700	9.8064**	4.3490
Intercept	114.41	42.8800	-19.0310	18.9000
R-Squared	39.98%		43.74%	
F-Statistic	2.5904		3.0235	
P-Value	0.0210		0.0089	

** and * denote significant at the 5% and 10% levels.

Table 4. Causal Flows and Tests of Symmetric Feedback Between the Probabilities that the Individual Markets are in the Cooperative Phase during the Period from 5/80 to 9/82.

	IA	E. NE	W. NE	E. KS	W. KS	CO	TX	Omaha	Sioux
Illinois	<---	<---	<---> -1.787	<---	<---	<---	<---	<---	<---
Iowa		<---	<---> 0.102	---	<---	<---	--->	<---	--->
E. Nebraska			<---> 0.221	<---> 1.162	<---> 1.601	<---	<---> 3.152*	<---> 1.90	<---> 1.344
W. Nebraska				<---> 1.234	<---> -0.214	<---	<---> -0.310	<---> -0.107	<---> 2.416**
E. Kansas					<---> -0.257	<---	<---> 1.351	<---> -1.044	--->
W. Kansas						---	--->	---	---
Colorado							--->	--->	--->
Texas								<---	<---
Omaha, NE									<---> 1.415

** denotes the statistic is significant at the 5% level. A significant negative statistic denotes <--- and a significant positive statistic denotes --->.

Table 5. Causal Flows and Tests of Symmetric Feedback Between the Probabilities that the Individual Markets are in the Cooperative Phase during the Period from 7/84 to 7/86.

	IA	E. NE	W. NE	E. KS	W. KS	CO	TX	Omaha	Sioux
Illinois	<---	<---	<---	<---	<---	---	---	<---	---
Iowa		--->	--->	--->	---	--->	---	--->	--->
E. Nebraska			<---> 0.900	<---	<---	--->	---	<---> -0.992	<---> -2.036*
W. Nebraska				<---	---	<---	---	<---	--->
E. Kansas					---	--->	--->	---	--->
W. Kansas						---	--->	---	--->
Colorado							---	---	---
Texas									--->
Omaha, NE									

* denotes the statistic is significant at the 10% level. A significant negative statistic denotes <--- and a significant positive statistic denotes --->.

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