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Meat-Packer Conduct in Fed Cattle Pricing: Multiple-Market Oligopsony Power

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The exercise of market power across 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 oligopsony model of multiple-market conduct. The 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 meat-packers coordinate this pricing strategy across geographic markets. Tests reject independence of pricing conduct across geographic markets which suggests multiple-market market power is present. The extent of the market power also is consistent with the economic model. More market power is exercised across regions with the same meat-packing firms. However, the magnitude of the market power is small and decreased between the early and late 1980s.

Key words: meat-packer multiple-market conduct, noncooperative game theory, oligopsony power

Introduction

Producers, policymakers, and regulatory agencies are concerned about the exercise of market power in geographically dispersed commodity markets (U.S. General Accounting Office). Recently, markets for cattle, beef, hogs, and pork have been the focus of research [U.S. Department of Agriculture (USDA) February 1996] and public attention. Applied research in this area has used various procedures to make inferences about market power (Azzam and Anderson). The research which has examined market power across geographic areas implicitly assumes the boundaries of regional markets, or has attempted to identify the boundaries and draw market power inferences from the extent of price linkages across regional markets.

The classical approach to identifying regional markets involves estimating cross-market elasticities; inelastic responses identify boundaries and isolated markets (Stigler and Sherwin). In a few cases, regional quantity movements have been used to identify market boundaries [Elzinga and Hogarty; Hayenga, Koontz, and Schroeder (Part 2)]. As an alternative to measuring market boundaries, Scheffman and Spiller delineate antitrust markets which are consistent with the exercise of market power within *Department of Justice Merger Guidelines*.[1] Residual own-price elasticities are used to identify antitrust markets, which may or may not differ from the underlying economic market. However, the use of these procedures is limited by the availability and proprietary nature of the

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[1] The 1984 *Merger Guidelines* were revised and reissued in 1992 jointly by the Department of Justice and the Federal Trade Commission.

quantity data needed to examine product shipments or estimate elasticity models. Further, the Scheffman and Spiller approach is contingent on policy guidelines which are subject to change.

As a result, applied economists often resort to examining regional price dynamics. The methods used vary from correlations to vector autoregression and error correction models (Goodwin and Schroeder 1990, 1991; Hayenga and O'Brien; Koontz, Garcia, and Hudson 1990; Schroeder and Goodwin; Slade; Uri, Howell, and Rifkin; Uri and Rifkin). However, these procedures suffer from several weaknesses that can produce misleading conclusions about market boundaries and inappropriate market power inferences. First, it is not always clear whether correlated or uncorrelated price movements between markets imply a market boundary because transaction costs have been ignored. Geographic marketplaces which generally trade will have low correlations during periods when price differentials are less than transaction costs and no commodity is traded. Similarly, low correlations can exist between markets which do trade when the flows are not unidirectional. Second, the comovement of prices in geographic markets may be due to general supply and demand factors influencing both markets. Seasonal price variation, from weather-related seasonal production, will result in strong price correlations; yet the geographic marketplaces may be separate economic markets. The problem with these price dynamics studies is that these empirical models are not derived explicitly from an economic model of oligopoly or oligopsony behavior such that dynamic relationships can be interpreted in the context of market power.

This article presents direct measures and a test of the competitiveness of meat-packer pricing conduct across multiple geographic fed cattle markets. Like the Scheffman and Spiller approach, we measure conduct directly related to the exercise of market power. Measuring the exercise of market power across multiple geographic fed cattle markets has not been done previously. The information should contribute to the body of knowledge about meat-packer conduct, which is being used in current policy discussions (USDA June 1996). Second, the model can identify markets with interactive pricing strategies, permitting an innovative procedure for defining market boundaries. Unlike price dynamics studies, this measure is not affected by the ignored transaction costs. Further, the empirical models are 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 (1993). The model is generalized to multiple markets in the next section. The economic model is a noncooperative game of fed cattle purchases by meat-packers. Meat-packers cannot form enforceable agreements, so if market power is exercised, it must be done through self-enforcing tacit agreements.

A meat-packer produces meat (y) from fed cattle (x) and other inputs (v). Fixed proportion production is assumed. The proportion of animal converted to meat is $1/k$. Profits of the ith meat-packer are

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

where 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 carcass beef 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 meat-packers, exogenous variables X, and random variations ξ.

In the repeated game, the value function of the ith meat-packer is the sum of current and discounted expected future profits:

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

where profits depend on that firm's pricing strategy s_t^i and strategies s_t^{-i} of all other firms, and δ is the discount rate. Nash equilibrium is the only reasonable equilibrium concept for a noncooperative game with 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 meat-packer to offer a higher price, secure a larger market share of the cattle procured, and sell more meat. However, when all meat-packers respond to this incentive, cattle prices are bid up to marginal revenue and there is no 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 strategy can deter cheating on the tacit agreement. In a punishment strategy, 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 the incentive to cooperate, or

(3) $$V_i(p') > \pi_i(p^*) + \delta V_i(p'') \qquad \text{for all firms.}$$

Equation (3) is the incentive constraint.

Green and Porter generalize this game. The result is an equilibrium punishment strategy that is more forgiving. They relax the assumption of perfect information where each firm observes the actions of other firms. Collusive equilibria remain possible but the punishment strategy is modified. Because noncooperative behavior can occur from random price variations, the strategy must be more forgiving. Meat-packers maximize value function (2) subject to a threshold strategy:

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

where μ is a threshold margin, p' and p'' are cooperative and noncooperative prices, and m_{t-1} is the margin between carcass beef price and an observable cattle price during the previous period. If the margin in the previous period is greater than threshold μ, firms offer the cooperative price p'. However, if the margin in the previous $T-1$ periods is less than the threshold, firms offer the 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 summarizing the multiple-period optimization problem. For a firm initially in the cooperative phase, the value function is

$$(5)\quad V_i(p') = \pi_i(p') + \text{Prob}\{\mu < m_t\}\delta V_i(p') + \text{Prob}\{\mu \geq m_t\}\left[\sum_{t=1}^{T-1} \delta^t \pi_i(p'') + \delta^T V_i(p')\right].$$

The incentive constraint for the threshold strategy is

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

where $p^* > p'$ is the price paid by the cheating firm. 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 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 on the tacit agreement. However, random price variations will cause margins to periodically cross the threshold. For the strategy to be credible, the players must then revert to pricing at single-period Nash levels. Players also may revert to Nash pricing when they tacitly renegotiate the level of market power exercised in the strategy.[2] 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 meat-packer 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).[3] The underlying idea 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:

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

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

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

[2] The game theoretic model has strong heuristic appeal. The model suggests that meat-packers bid aggressively for cattle when other meat-packers are bidding aggressively and do not bid aggressively when others are not. Meat-packers are balancing two incentives. They have the incentive to bid low prices for cattle. Doing so results in greater per unit profits. They also have the incentive to bid cattle away from other meat-packers. If successful, this results in greater total profits. The two incentives are in conflict, but given the small number of meat-packers in regional fed cattle markets, both of these behavioral regimes should be observed in price.

[3] Schroeter and Azzam also examine multiple-market conduct by meat-packers, but the conduct does not emerge through a punishment strategy.

where μ is a vector of threshold margins and m_{t-1} is the vector of margins of the previous period. The inequality is violated if any of the vector elements violate the inequality. If any firm fails to conform to the collusive agreement, all firms revert to noncooperative behavior in all K markets.

The value function of a firm in multiple markets is

$$V_i(p') = \sum_{k=1}^{K} V_{ik}(s_t) = \sum_{k=1}^{K} \left\{ \pi_{ik}(p') + \text{Prob}\{\mu < m_t\}\delta V_{ik}(p') + \text{Prob}\{\mu \geq m_t\}\left[\sum_{t=1}^{T-1} \delta^t \pi_{ik}(p'') + \delta^T V_{ik}(p')\right]\right\}. \tag{9}$$

The incentive constraint for the threshold strategy is pooled across markets:

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

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

The pooled incentive constraint is the key to exercising market power in multiple markets. Multiple-market contact cannot reduce the ability of firms to collude. Firms can always treat each market in isolation. The pooling can only relax binding incentive constraints in individual markets, increase the set of equilibrium strategies, and increase collusive profits. However, if benefits and costs of collusion increase proportionally they will offset each other. Bernheim and Whinston show that the benefits of collusion are greater than costs in spatial markets when firms have increasing returns to scale. These conditions describe the fed cattle market and meat-packing firms (Connor). The threat of severe punishments supports very collusive profits in the cooperative periods. However, there are limits. 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 tacit communication and trust between players must increase. Thus, identifying the set of relevant markets where multiple-market pricing is coordinated is a statistical exercise.

Because the model relies on measures of conduct, transaction costs are included implicitly. If the costs of coordinating multiple-market conduct are excessive, the exercise of market power across multiple markets will not occur. This is an advantage over studies which have examined price dynamics. Likewise, if the transaction costs of tacitly developing and monitoring a cooperative pricing strategy are too large for firms within a single market, the exercise of market power will not occur within individual markets.

The single-market model implies that the exercise of market power in individual markets results in a discontinuous pattern in prices. The multiple-market model implies the exercise of market power across geographic markets results in discontinuous patterns being coordinated across relevant markets. There should be high correlation in the movement of the markets between the cooperative and noncooperative phases. Finding this correlation implies cooperation between players across markets and identifies relevant markets. This is the statistical exercise. The extent of the cooperation can be measured by the strength of the correlation.

Methods

The econometric model for a single market is summarized in the beginning of this section. The single-market model provides information about when each individual market is in the cooperative or noncooperative phase. The comovement of this probability of cooperation across models for various geographic markets is measured to assess the coordination of market power. The multiple-market measures of market power end the section.

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

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

where p_j denotes the price offered by the jth firm, $j\neq i$. The change in procurement given a change in cattle price is a structural parameter:

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

The conjecture is zero in noncooperative periods and is positive in cooperative periods:

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

The conjecture measures the average change in cattle price offered by other firms as meat-packers switch between phases.[4]

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_0 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

$$(14)\qquad y_t = X_t\eta + \xi_t,$$

where X_t is the tth row of an exogenous variable matrix, η are parameters, and ξ_t an error term. Exogenous variables include feeder cattle prices, corn prices, interest rates, and temporal dummy variables. Daily regional fed cattle supply is not assumed to be a function of fed cattle price. Rather, prices divide the given number of animals between meat-packers.

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

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

[4] Pricing strategies are restricted to be strategic complements, as opposed to allowing the empirical model to determine whether the strategies are complements or substitutes. (See Bulow, Geanakoplos, and Klemperer; Tirole.)

where $\epsilon_{2t} = \phi\epsilon_{1t}$. Assuming $\epsilon_{1t} \sim N(0,\sigma^2)$, results in $\epsilon_{2t} \sim N(0,\phi^2\sigma^2)$. The average conjecture is identified, $\beta_0 = (1 - \phi)$, and α is a vector of reduced-form parameters.

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

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

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

$$h(m_t|X_t, I_t) = I_t/(\sigma\sqrt{2\pi}) \exp\{-(m_t - X_t\alpha)^2/2\sigma^2\} + (1 - I_t)/\phi\sigma\sqrt{2\pi} \exp\{-(m_t - X_t\alpha\phi)^2/2\phi^2\sigma^2\}, \tag{17}$$

and parameter estimation is straightforward. Since the sequence of changes is not known, a process to classify each observation must be specified. A Bernoulli process is used and has been used in all previous applications (e.g., Porter 1983b).[5] With a Bernoulli process, the cooperative and noncooperative phases occur with probabilities λ and $(1-\lambda)$.

The density for observation m_t is

$$h(m_t|X_t) = \lambda/(\sigma\sqrt{2\pi}) \exp\{-(m_t - X_t\alpha)^2/2\sigma^2\} + (1 - \lambda)/\phi\sigma\sqrt{2\pi} \exp\{-(m_t - X_t\alpha\phi)^2/2\phi^2\sigma^2\}. \tag{18}$$

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

The switching regression can be used to measure the probability that each observation is in the cooperative regime. Following Kiefer, the series of probabilities are calculated using Bayes rule:

$$\omega_t^* = \frac{\lambda^* h(m_t|X_t, \alpha^*, \sigma^*, I_t = 1)}{\lambda^* h(m_t|X_t, \alpha^*, \sigma^*, I_t = 1) + (1 - \lambda^*)h(m_t|X_t, \alpha^*, \phi^*, \sigma^*, I_t = 0)}. \tag{19}$$

The ω_t^* are estimates of I_t. From Lee and Porter,

$$I_t^* = \begin{cases} 1 & \text{if } \omega_t^* \geq ½ \\ 0 & \text{if } \omega_t^* < ½. \end{cases} \tag{20}$$

The ω_t^* and I_t^* series provide complementary information about conduct in multiple markets. The comovement in I_t^* across geographic markets provide direct information about parallel changes in the state of cooperation and the exercise of multiple-market market power. The I_t^* series are estimates of the actual state of cooperation. The ω_t^* variables provide similar information in a different random variable. The comovements in ω_t^* across markets provide information about parallel changes in the probability of cooperation. The probabilities tell about the pricing environment. The densities of the two random variables suggest different methods of analysis.

Contingency tables are used to test the pairwise independence of the I_t^* series. A 2×2

[5] The economic model suggests a T-Markov process. However, estimating a T-Markov switching regression is 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, Pearce, and Stachetti). The Bernoulli process is flexible enough to approximate a T-Markov process and may be robust to alternative processes.

Table 1. Contingency Table Structure

I^*_{1t}	I^*_{2t} Cooperative	Noncooperative	Total
Cooperative	p_{cc}	p_{cn}	p_{c+}
Noncooperative	p_{nc}	p_{nn}	p_{n+}
Total	p_{+c}	p_{+n}	

table is presented in table 1. The subscripts 1 and 2 denote different markets and p_{ij} are probabilities. In the absence of multiple-market market power, movements of the different I^*_{kt} series between cooperative and noncooperative regimes should be independent. The null hypothesis is

$$\text{(21)} \qquad H_0\text{: } p_{ij} = p_{i+} \cdot p_{+j} \quad \text{for} \quad i = c, n \quad \text{and} \quad j = c, n.$$

If the pricing conduct within two markets is independent, the probability that both markets are in the cooperative state (p_{cc}) is equivalent to the probability that market 1 is in the cooperative state (p_{c+}) multiplied by the probability that market 2 is in the cooperative state (p_{+c}). Rejecting the null hypothesis for one combination implies rejection of the hypothesis for all combinations. Strength of the multiple-market cooperation is measured by the probability that both markets are in the cooperative state (p_{cc}).

The probabilities that pairs of markets are in the cooperative state are summarized in a regression model. The probability of cooperation is modeled as a function of regional market characteristics, some implied by the economic model. The market characteristic variables are distance between the two regions, total number of meat-packing firms in both regions, number of meat-packing firms which are common to both regions, average volume of cattle slaughtered in the two regions, average four-firm concentration ratio for the two regions, and a dummy variable for whether or not either market is a terminal market. The markets are classified into one of three regions and a same-region dummy variable is also included. The three regions are the Upper Midwest, Central Plains, and Southern Plains.[6] Firm number and composition explanatory variables are similar to those used by Porter (1985). The greater the number of meat-packing firms, the less likely tacit collusion will be an equilibrium pricing strategy. However, the greater the number of firms which are common between two regions, the more likely an collusive equilibrium strategy exists. Further, the greater the distance between two regions, the less likely the meat-packers 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. Our model suggests the same hypothesis. However, the composition of the firms is more important. The potential effect of a terminal market and market volume on the probability of cooperation is not known a priori.

[6] Illinois, Iowa, Eastern Nebraska, and the terminal markets are classified in the Upper Midwest region. Colorado and Western Nebraska are in the Central Plains region, and Eastern Kansas, Western Kansas, and Texas are in the Southern Plains region.

Information from Granger causality tests are used to measure the pairwise dynamic interactions of the probabilities that the kth market is in the cooperative regime, the ω^*_{kt} series. The variables ω^*_{1t} and ω^*_{2t} are rewritten as x_t and y_t. All series are stationary or exhibit a deterministic trend. Standard Granger-type models are used as follows:

$$x_t = \rho_0 + \sum_{i=1}^{p} \rho_{1i} x_{t-i} + \sum_{j=1}^{q} \rho_{2j} y_{t-j} + u_{1t} \quad \text{var}(u_{1t}) = \sigma_1, \tag{22}$$

and

$$y_t = \psi_0 + \sum_{i=1}^{p} \psi_{1i} y_{t-i} + \sum_{j=1}^{q} \psi_{2j} x_{t-j} + u_{2t} \quad \text{var}(u_{2t}) = \sigma_2, \tag{23}$$

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

Autoregressive models using only lagged values of the dependent variables also are estimated. Let the error variances of the autoregressive models for x_t and y_t be denoted φ_1 and φ_2. Geweke defines measures of the linear association between two variables as:

$$P_{x\rightarrow y} = \ln(\varphi_1/\sigma_1) \qquad \text{and} \qquad P_{y\rightarrow x} = \ln(\varphi_2/\sigma_2). \tag{24}$$

These statistics measure the strength of the linear causality from x to y and from y to x. In the case of feedback, where causality occurs in both directions, the measures can be used to determine which causal relationship is largest. Symmetry is tested with the following statistic:

$$P_{x\leftrightarrow y} = [N{\cdot}P_{x\rightarrow y} - 1/3]^{1/2} - [N{\cdot}P_{y\rightarrow x} - 1/3]^{1/2}, \tag{25}$$

where N is the number of observations. The statistic approximates a normal(0,2) under the null hypothesis of symmetric feedback (Geweke).

In the following analysis, causality results are reported between pairs of markets using small sample F-tests, and where feedback occurs, the test of symmetry is reported to identify any dominant market. The test results will reveal which regional fed cattle markets lead multiple-market pricing conduct.

Results

The daily fed cattle price data are from eight direct trade regions defined by the U.S. Department of Agriculture, Agricultural Marketing Service, 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, Nebraska, and Sioux City, Iowa. A majority of total U.S. fed cattle sales occur in these eight regions. The USDA daily boxed beef cutout value series for choice 550–700 pound carcasses is the carcass beef price used to calculate the margin series.

A potential difficulty with this model is that the inference about market power requires

Table 2. Summary Statistics of the Probability That Each Regional Market Is in the Cooperative Phase

	No. Obs.	Mean	SD	Minimum	Maximum	% Coop	% Noncoop
First Period[a]							
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
Eastern Nebraska	608	0.5776	0.1819	0.3208	0.9999	0.4967	0.5033
Western Nebraska	608	0.2705	0.2249	0.0608	0.9999	0.1349	0.8651
Eastern Kansas	608	0.2989	0.1926	0.1192	0.9987	0.1250	0.8750
Western 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[b]							
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
Eastern Nebraska	526	0.0593	0.0964	0.0207	0.9800	0.0114	0.9886
Western Nebraska	526	0.0465	0.1211	0.0043	0.9995	0.0152	0.9848
Eastern Kansas	526	0.1670	0.1910	0.0049	1.0000	0.0608	0.9392
Western 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

[a] The first period is from May 1980 to September 1982.
[b] The second period is from July 1984 to July 1986.

identifying a component in the margin equation error term. The difficulty is that shocks other than changes in conduct may influence margin levels. Thus, 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 1993 reveals two periods of relative stability: May 1980 through September 1982 and July 1984 through July 1986 (Ward 1988; *Meat Industry Magazine*; Koontz). These two periods are used in the analysis. Further, variation in supply is a major factor which may lead to changes in margins. In response to this concern, correlations between the measures of conduct, that is, the probabilities of cooperation, and supply variables were examined. Correlations were examined between the probabilities and temporal dummy variables and between aggregated probabilities and cattle numbers from the monthly USDA *Cattle on Feed* report. The probabilities are not correlated with supply variables.

Koontz, Garcia, and Hudson (1993) presented results of the single-market models. In summary, market power persisted in all regional fed cattle markets. However, the extent was relatively small in dollar per animal losses and less market power was exercised in the second period. Summary statistics of the probability of cooperation (ω_t^*) and the state of cooperation (I_t^*) series are presented in table 2. The means, standard deviations, minimums, and maximums are of the ω_t^* series. The last two columns report the percentage of time that each market is in the cooperative ($I_t^*=1$) and noncooperative ($I_t^*=0$) regimes.

Table 3. 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 Same or Previous Four Business Days

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

[a] The top number refers to the first period, May 1980 to September 1982, and the bottom number refers to the second period, July 1984 to July 1986.

The results clearly show more cooperation in the first time period and thus more market power is being exercised in the individual markets.

The probability that a pair of the geographic markets are both in the cooperative state are presented in table 3. Estimates are aggregated. The I_t^* series are aggregated over the current and previous four business days. This is done assuming players in the different geographic markets need time to observe and react to prices in other markets. Further, fed cattle markets are for the most part a weekly market (Ward 1992). That is, meat-packers modify pricing decisions weekly. Results show the linkages between pairs of markets over a week. Independence of markets in movement between cooperative and noncooperative regimes is rejected. Fisher's Exact Test is used (Bickel and Doksum). Most of the tests are significant at the 1% level and all are significant at the 5% level with five exceptions. In the first period, independence is rejected at the 10% level between Eastern Nebraska and Illinois, and between Eastern Nebraska and Colorado.[7] In the second period, independence is not rejected between Colorado and Texas and between Illinois and Sioux City. Independence cannot be tested between Illinois and Colorado in the second sample because the markets are never jointly in the cooperative phase; the test breaks down. However, there can be no multiple-market behavior in this case.

Multiple-market market power is exercised across geographic fed cattle markets. The tests of independence are rejected. However, as with the single-market model results, the extent of the market power is small and much lower in the second time period. Most of

[7] Caution must be used in interpreting the size of the joint probability. Size should not be linked to significance. Rather, it is the size relative to the sizes of the marginal probabilities; see equation (21).

Table 4. Regression Model Results Where the Probability That Various Market Pairs Are in the Cooperative Phase Is Explained as a Function of Regional Market Characteristics

	First Period Model[a]		Second Period Model[b]	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Distance	−2.1283	2.8150	−0.2989	1.0190
Same-region dummy	15.9620*[c]	8.3760	−1.1513	2.4520
Volume	0.00009	0.0024	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^2	39.98%		43.74%	
F-Statistic	2.5904		3.0235	
p-Value	0.0210		0.0089	

[a] The first period is from May 1980 to September 1982.
[b] The second period is from July 1984 to July 1986.
[c] Two asterisks and one asterisk denote significance at the 5% and 10% levels, respectively.

the joint probabilities are small. The Illinois, Iowa, Eastern Nebraska, Omaha, and Sioux City markets interact the most closely. The joint probabilities are largest between markets in the Upper Midwest region. 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 probabilities from table 3 are presented in table 4. In the model of first period, 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.[8] If a pair of markets are in the same geographic region (i.e., Upper Midwest, Central Plains, and Southern Plains), the markets exhibit a 16% higher probability of jointly being in the cooperative phase. This result suggests market boundaries are consistent with this three-region classification. A 10% increase in the average four-firm concentration ratio of two regions leads to an 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 meat-packing industry experienced excess capacity during the entire mid-to-late 1980s, and excess capacity was likely large in regions with high concentration. Thus, pricing was the most competitive in high concentration regions. Variables capturing the number of firms and the number of firms common to both regions are both insignificant. Although, these measures are 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

[8] Because the dependent variable is not distributed normal, parameters and standard errors were calculated by bootstrapping the residuals.

Table 5. Causal Flows between the Probabilities That Individual Markets Are in the Cooperative Phase and Statistics for the Test of Symmetric Feedback, May 1980 to September 1982

Market	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

Note: Two asterisks denote the statistic is significant at the 5% level. A significant negative statistic denotes asymmetric feedback with the ← direction being the largest and a significant positive statistic denotes asymmetric feedback with the → direction being the largest.

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 similar 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, albeit the magnitude of the effect is quite small. If one of the two markets in a pair is a terminal market, the pair is 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 5 and 6 present the results from the Granger causality tests between ω_t^* series. Arrows denote significant causal relationships. The statistic reported under an arrow denoting feedback is the test of symmetry. The first period results are in table 5 and the second period are in table 6. The results suggest there is considerable interaction between the ω_t^* series across geographic markets. There is no one market which leads multiple-market conduct. However, there are groups of markets which lead, there are markets which follow the leading markets, and there are pairs of markets which do not interact.

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 considerable feedback between Eastern Nebraska, Western Nebraska, Eastern Kansas, Western Kansas, Texas, and the terminal markets, and much of the feedback is symmetric. Only the feedback between Eastern Nebraska and Texas is asymmetric with

Table 6. Causal Flows between the Probabilities That Individual Markets Are in the Cooperative Phase and Statistics for the Test of Symmetric Feedback, July 1984 to July 1986

Market	IA	E. NE	W. NE	E. KS	W. KS	CO	TX	Omaha	Sioux
Illinois	⟵	⟵	⟵	⟵	⟵	---	---	⟵	---
Iowa		⟶	⟶	⟶	---	⟶	---	⟶	⟶
E. Nebraska			⟷ 0.900	⟵	⟵	⟶	---	⟷ −0.992	---
W. Nebraska				⟵	---	⟵	---	⟵	⟷ −2.036*
E. Kansas					---	⟶	⟶	---	⟶
W. Kansas						---	⟶	---	---
Colorado							---	⟵	⟶
Texas								---	---
Omaha, NE									⟶

Note: One asterisk denotes the statistic is significant at the 10% level. A significant negative statistic denotes asymmetric feedback with the ← direction being the largest and a significant positive statistic denotes asymmetric feedback with the → direction being the largest.

Eastern Nebraska being the leading market. There are also a few markets which do not interact. Eastern Kansas and Iowa, Colorado and Western Kansas, Western Kansas and the terminal markets have no significant causal relationships. The results suggest conduct in Nebraska and Kansas lead conduct in other regional markets during the May 1980 to September 1982 time period. Further, the amount of causality and feedback suggest the extent of fed cattle market boundaries was large during this time period. Causal relationships and feedback are the largest 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 also are many more cases where markets do not interact. Iowa, Eastern Kansas, and Western Kansas are leader markets. Although, Western Kansas does not interact with several markets. Illinois, Eastern Nebraska, and Western Nebraska are follower markets. Colorado and the terminal markets are both leaders and followers. The probability of cooperation in Texas does not interact with any markets with the exception of the two Kansas markets. Texas is the most independent market and Western Kansas is the second most independent. The results suggest conduct in Iowa and Kansas lead conduct in other regional markets during the July 1984 to July 1986 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. The absence of causality suggests meat-packers treated pricing within regional markets as independent decisions. 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.

It is interesting to compare the results of this study with results of some of the other market power studies of beef-packing and with results of the single-market model. The conclusions here are consistent with other research. This work adds to the growing list of New Empirical Industrial Organization (NEIO) research which has found evidence of market power exercised by beef-packers. While a variety of empirical models and data have been employed, the results consistently reveal evidence of market power exercised in fed cattle markets (Azzam and Anderson). However, the magnitude of the market power is small, usually 1–3% of average price and occasionally larger or not present. The NEIO studies' estimates are larger than those of recent studies using transaction price data (Texas Agricultural Market Research Center) which follow the structure-conduct-performance approach. Concentration effects in the transaction data are less than 1%. The losses found in Koontz, Garcia, and Hudson (1993) are consistent with the 1–3% figures.[9] Further, the single-market model results are consistent with the increased use of market power in regions with common firms. The uniqueness of the work here is that this is the first evidence of multiple-market conduct in regional fed cattle markets.[10]

The results here are also consistent with the price dynamics studies. Goodwin and Schroeder (1991) and Hayenga, Koontz, and Schroeder (Part 3) make similar conclusions about which regions lead price discovery. The advantage of this work, unlike the dynamic multipliers from time-series models, is the direct link between the measurements of price behavior and the implied noncompetitive conduct.

Conclusions

A noncooperative game-theoretic model of meat-packer pricing conduct across geographic markets is developed. 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 May 1980 to September 1982 and separately for the time period July 1984 to July 1986. The geographic fed cattle markets examined include the major direct and terminal markets in the Upper Midwest, Central, and Southern Plains states.

The economic model suggests that exercise of market power in purchasing fed cattle requires meat-packers to follow a two-phase pricing strategy: low prices are paid during cooperative phases and high prices are paid during noncooperative phases (relative to 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. Meat-packer 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. There is evidence that the Upper Midwest markets (Illinois; Iowa; Eastern Nebraska; Omaha, Nebraska; and Sioux City, Iowa), the Central Plains markets (Western Nebraska and Colorado), and the Southern Plains markets (Eastern Kansas, Western Kansas, and Texas) each constitutes an economic market. However, Colorado and Texas are largely independent. There is also evidence that the more meat-packers that are common within two

[9] However, the results here are based on models of daily margin changes for eight regions while previous research has used annual or quarterly data for the entire U.S. Azzam and Schroeter is the one other study that examined direct impacts of market power on regional prices, using data for 13 regions.

[10] Schroeter and Azzam examine, but do not find, multiple-market conduct between beef- and pork-packing industries.

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.

Several general implications can be drawn from this research. First, coordination pricing strategies across markets suggest that market power has been exercised across fed cattle markets. Second, the magnitude of our results indicates that losses imposed by the less than competitive structure are relatively small. Third, our findings indicate that market power is not constant over time nor uniform over space. Meat-packers operate in a dynamic environment in which they adjust pricing strategies to varying market conditions. The strongest exercise of market power was found from May 1980 to September 1982. Maintaining cooperative strategies during the mid-1980s may have been more difficult because of supply conditions. Nevertheless, between July 1984 and July 1985, there is evidence of coordinated pricing. Changing conduct across markets and over time highlights the difficulty and importance of continued monitoring for competitive performance. Changing conduct also suggests the importance of developing a more comprehensive understanding of the factors influencing conduct and competition.

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