MEATPACKER CONDUCT AND PRICE DYNAMICS:
AN INVESTIGATION OF LIVE CATTLE MARKETS

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(ABSTRACT)

Noncooperative game theory is used to model the margin between daily boxed beef and regional live cattle prices. The model suggests a specific discontinuous pattern will be observed in margin behavior if market power is exercised by meatpackers. This pattern was tested for, and found to persist, in four central U.S. markets. The monetary extent of the market power is quantified.
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During the past two decades, there has been a significant increase in meatpacker concentration levels, particularly in beef slaughter and boxed beef processing (Ward 1987; Ward 1988). These changes have accentuated the concern over oligopsony power in live cattle markets and its effects on producer welfare. While there is concern over market power in the beef sector, its effects are difficult to quantify. Previous research into the livestock industries has focused on intermediate and long-run structure-performance relationships (e.g. Quail et al. and Schroeter). There have been few attempts, however, to examine the effects of market power on the short-run pricing process. Similarly, explicit models of conduct to explain market behavior in this industry have not been formulated.

The objective of this paper is to determine the existence and extent of oligopsonistic market power exercised by meatpackers in procuring live cattle. A model of market conduct based on noncooperative game theory is developed to explain the interaction among meatpackers in purchasing live cattle. The economic model, couched in a trigger pricing strategy, suggests that for an equilibrium to persist, the meatpackers will follow a strategy with two actions: a cooperative phase where low prices are paid for cattle, and a noncooperative phase where cattle is purchased more aggressively at more competitive levels. If market power is exercised, discontinuities in live cattle prices will exist as meatpackers switch between cooperative and noncooperative phases of the strategy. Econometric analysis is conducted using direct marketing prices reported in various areas in the High Plains and Corn Belt to determine the presence of the cooperative/noncooperative dynamics. Measures of market power are generated and the results are assessed in terms of the structural characteristics of the markets.

Oligopsony Model of Live Cattle Procurement

The meatpacker procurement of live cattle is modelled as a noncooperative game. Specifically, a model is formulated which characterizes the behavior of multiple players in a single marketplace. A meatpacker produces meat (y) from live cattle (x) and a vector of other inputs (v).
Following Schroeter, the production technology is assumed to be Leontief between live animals and other inputs, $y = \min[x/k, g(y)]$, where $l/k$ is the proportion of live animal converted to meat. The profit function is specified incorporating stochastic events in the live cattle market, and the actions of other players which affect the profits of each individual player. The profit function for the $i$th firm in a given procurement region is

$$\pi_i(r_t, s_{t-1}^i, s_t^i, z_t) = [r_t - s_t^i k] y_t^i(s_{t-1}^i, s_t^i, W, \xi) - c_i(z_t, y_t^i)$$

where $t$ denotes time, $\pi_i$ the profits of the $i$th firm, $r_t$ the wholesale price of meat, $s_t^i$ the strategy of the $i$th firm, $s_{t-1}^i$ the strategies of other firms, $z_t$ a vector of other input prices, $y_t^i$ the supply of animals procured, $W$ a set of exogenous factors, $\xi$ the total number of animals available for procurement in a given region, and $c_i$ the cost function of the $i$th firm.

The wholesale meat price, $r_t$, and the supply procured by the $i$th meatpacker, $y_t^i$, are influenced by stochastic events. The variable $\xi$ is used to indicate that the number of animals available for procurement in a given region has a random component. The quantity of meat available for sale, $y_t^i$, by the $i$th firm depends on the quantity procured. The procured quantity is influenced by the strategy played by the meatpacker, $s_t^i$, strategies played by other firms, $s_{t-1}^i$, and a set of exogenous factors, $W$. The choices of strategies and the actions of firms across the industry are not directly observable by the $i$th firm. The information used by the $i$th firm only contains aggregate market prices.

In an intertemporal setting, the problem for the $i$th firm is to maximize the sum of the discounted expected profits, $V_i$, through a strategy choice $s_t^i$

$$V_i(s_t) = \mathbb{E} \left[ \sum_{t=0}^{\infty} \delta^t [r_t - s_t^i k] y_t^i(s_{t-1}^i, s_t^i, W, \xi) - c_i(w_t, y_t^i) \right]$$

subject to the reaction function of the firm:

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

where $\mathbb{E}$ is the expectations operation, $\delta$ is the discount rate, $\mu$ is the trigger margin level, $p'(r)$ and $p''(r)$ are two base live cattle price levels which are a function of the meat price where $p' < p''$, and $m_{t-1} = r_{t-1} - p_{t-1} k$ is the regional margin from the previous period. The reaction function (3)
incorporates a trigger margin strategy in procurement which permits variability in price reflecting movement from cooperative to noncooperative periods (Green and Porter; Porter 1983a). The margin is the net price for the meatpacker and therefore it is incorporated into the pricing strategy. If the margin from the previous period is less than the trigger level \( \mu \), then the current live cattle offer is at the cooperative price level in the current period \( p' \); however, if the margin in the previous \( T \) periods was above the trigger level then the current offer is at a noncooperative level \( p'' \).

Substituting the reaction function (3) into the objective function (2), the multiple period optimization problem can be written as a recursive equation. For a firm initially in the cooperative period, the objective function (2) can be rewritten as:

\[
V_i(p') = \pi_i(p') + \Pr(\mu > m_t(W, \xi)) \cdot \delta V_i(p') \\
+ \Pr(\mu \leq m_t(W, \xi)) \cdot \left[ \sum_{r=1}^{T-1} \delta^r \pi_i(p'') + \delta^T V_i(p') \right].
\]

That is, \( V_i(p') \) is the present period expected profits plus the expected discounted value next period. The expected value next period is the value when cooperative pricing is continued in the next period multiplied by the probability the market price stays under the trigger level, plus the returns expected during a noncooperative period multiplied by the probability of its occurrence.

The observable market prices resulting from the trigger strategy and the optimization of (4) reflects the actions in the strategy. At \( p' \), where \( \pi (p') > \pi (p'') \), there is an incentive to cheat. To reduce the occurrence of cheating the oligopsony market never prices as low as a monopsony situation during cooperative periods. Also, to punish cheating, when it appears that a firm is deviating from \( p' \), all firms will price at \( p'' \) for \( T-1 \) periods (where \( p'' > p' \)). The theoretical model suggests that a discontinuous pattern of prices will emerge over time as the randomness in supplies, or cheating, pushes the margin below the trigger level and firms temporarily revert to pricing noncooperatively. The econometric analysis below examines market data for the presence of this discontinuous pattern.
Econometric Model of Oligopsony Behavior

The first-order conditions for maximizing profits of a meatpacking firm and the results from the economic model are used to derive an econometric model of margin behavior. The profit function for the $i$th firm is:

$$\pi_i = (r - p_i k) \ y_i(p_i, p_{-i}) - c_i(y_i)$$

where $p_i$ is the price of the $i$th firm, $p_{-i}$ is an n-1 vector of prices offered by other firms. The first order conditions for maximizing the profit function through the choice of price are:

$$\frac{\partial \pi_i}{\partial p_i} = (r - p_i k) \ \frac{\partial y_i}{\partial p_i} + \sum_{j \neq i} (\frac{\partial y_i}{\partial p_j}) (\frac{\partial p_j}{\partial p_i}) - ky_i - \frac{\partial c_i}{\partial y_i} = 0$$

where $p_j$ denotes the price offered by the $j$th firm, $j \neq i$.

Several assumptions are required to permit estimation of equation (6). First, the marginal cost component for other factors is assumed constant or $\frac{\partial c_i}{\partial y_i} = \alpha_i$. This implies that labor and energy marginal costs for the individual plants do not vary over the time periods of the analysis.

Second, the price response to live cattle price offers are equal across firms:

$$\frac{\partial y_i}{\partial p_j} = \frac{\partial y_i}{\partial p_k} = \ldots = \frac{\partial y_i}{\partial p_i} = -\frac{\partial y_i}{\partial p_i}.$$

This assumption is implicit in the economic model and without it the model results address pricing of differentiated products. Third, the symmetry of player strategies in the economic model results in all other firms responding equally to a change in the $i$th firm's offer price:

$$\frac{\partial p_j}{\partial p_i} = \frac{\partial p_k}{\partial p_i} = \ldots = \frac{\partial p_i}{\partial p_i}.$$

Finally, it is assumed that the change in procurement by any firm in response to a *ceteris paribus* price change is a constant, $\frac{\partial y}{\partial p_i} = \gamma$.

Using these assumptions and equations (7) and (8), the first-order condition (6) can be rewritten as:

$$\frac{(r - p_i k) (\gamma) [1 - (\frac{\partial p_j}{\partial p_i}) (n-1)] - k y_i - \alpha_i}{\gamma} = 0.$$
\( \partial p_y / \partial p_i = \beta = \begin{cases} \beta_0 > 0 & \text{if } m_t \text{ is in the cooperative regime} \\ 0 & \text{if } m_t \text{ is in the noncooperative regime} \end{cases} \)

where \( \beta \) is a function and \( \beta_0 \) is a constant. Incorporating the conjecture structure (10), equation (9) can be rewritten as

\( m_t = \frac{\alpha_i - k}{\gamma \psi} y_t^i. \) (11)

Due to data limitations, several steps are taken to formulate an estimable model from (11). First, because only aggregate price data are available, the first-order conditions are summed over the n-players in the regional market. Denoting \( y \) is the regional aggregate supply (i.e., \( y_t = \Sigma y_t^i \)), and dividing both sides by the number of firms, \( n \), yields

\( m_t = \frac{\alpha + (k/n)}{\gamma \psi} y_t \) (12)

where \( p_t = \Sigma p_t^m/n \) is the live cattle price aggregated over all meatpackers in the region and \( \alpha = \Sigma \alpha_i/n \) is the mean marginal cost of other inputs.

Second, due to the lack of daily quantity data, it is necessary to substitute a function for \( y_t \) which expresses live animal supply in terms of exogenous factors. The daily aggregate live cattle supply is not own price responsive but rather is influenced by seasonal factors, factors affecting the future profitability of feeding, and randomness. The aggregate supply function is represented as a linear function of exogenous factors and a random error:

\( y_t = W_t' \eta + \xi_t \) (13)

where \( W_t \) is a set of the exogenous factors and the term \( \xi_t \) is an error.

Substituting the supply function (13) into the margin equation (12) yields the following

\( m_t = \frac{\alpha + (k/n)}{\gamma \psi} [W_t' \eta + \xi_t] \)

or through condensing structural parameter notation.

\( m_t = Z_t' \alpha / \psi + (1/\psi) \epsilon_t \) (14)

where the term \( \alpha / \psi \) denotes elements of vector \( \alpha \) divided by the function \( \psi = [1 - \beta (N - 1)] \).

The margin behavior can be represented in terms of a conditional regression where
(15) \[ m_t = Z_t' \alpha / \psi + (1/\psi) \varepsilon_t \] if \( m_t \) is in the cooperative regime and
\[ m_t = Z_t' \alpha + \varepsilon_t \] if \( m_t \) is in the noncooperative regime.

By the nature of the proportional shift in parameter values and error term assesses the two regimes it is possible to transform the model (15) into a more useful form.

(16) \[ m_t = Z_t' \alpha + \varepsilon_{1t} \] if \( m_t \) is cooperative and
\[ m_t = Z_t' \alpha \phi + \varepsilon_{2t} \] if \( m_t \) is noncooperative.

where \( \phi = \psi_0 \) and \( \varepsilon_{2t} = \phi \varepsilon_{1t} \), so that given the first error term is distributed normal \( \varepsilon_{1t} \sim N(0, \sigma_1^2) \), the second error term has a proportional shift in variance \( \varepsilon_{2t} \sim N(0, \phi^2 \sigma_1^2) \). The transformation is useful because the variance of the conjecture \( \beta_0 \), can be calculated from \( \phi \), but not from \( (1/\psi_0) \).

Few of the structural parameters are identified, however, \( \beta_0 \) is, albeit with some subjectivity:

(17) \[ \beta_0 = (1 - \phi) / (n - 1). \]

The number of major firms, \( n \), which procure in the market must be known \textit{a priori}, and has been assessed through market case studies.

This switching model (16) estimated using a simple Bernoulli switching regression. The two regimes, cooperative and noncooperative, are assumed to appear with probability \( \lambda \) and \( (1 - \lambda) \).

This assumption is an approximation to the regime switching process suggested by the economic model and is standard in applications of the Green and Porter model (see Lee and Porter, and Porter 1983b). The error terms associated with both regimes are assumed to be distributed normal therefore, the density of an arbitrary observation \( m_t \) is:

\[
h(m_t) = \lambda / \sqrt{2\pi} \sigma_1 \exp \{- (m_t - Z_t' \alpha)^2 / 2\sigma_1^2 \}
\]

\[ + (1-\lambda) / \sqrt{2\pi} \phi \sigma_1 \exp \{- (m_t - Z_t' \alpha \phi)^2 / 2\phi^2 \sigma_1^2 \}. \]

Maximum likelihood estimates for the parameters are found by maximizing the nonlinear log-likelihood function with an iterative method and are denoted \( \theta^* = (\alpha^* \sigma_1^* \phi^* \lambda^*) \).

In the presence of the switching model, which can be tested through the likelihood ratio, the expected gains to the regional oligopsony can be calculated.\(^1\) During cooperative periods the expected level of meatpacker margins are

\[ ^1\text{The restricted model implies a single regime, or } \phi = 1, \text{ so that the number of restrictions equals one.} \]
(18) \( m^c = \bar{Z}\alpha^* \).

During noncooperative periods the margin is reduced by the level of proportional shift parameter

(19) \( m^n = \bar{Z}\alpha^*\phi^* \).

The expected value of the margin under an equilibrium trigger primary strategy is then the combination of the cooperative and noncooperative regime margins weighted by the probability of observing each regime

(20) \( m^c = \lambda^* m^c + (1 - \lambda^*) m^n \).

The gains to cooperation are the margin level under the trigger strategy less the margin level under the noncooperative regime multiplied by the volume of cattle traded (converted to a boxed beef equivalent).

(21) Gains = (\( m^c - m^n \)) \cdot Volume.

These gains are the total dollars to regional meatpackers due to the existence of the trigger pricing strategy. With trigger price strategies, the strength of the collusion can be measured by the significance and size of the conjecture \( \beta_0 \), the probability of observing cooperation \( \lambda \), and expected gains to cooperation.

**Data and Modelling Results**

Price quotes from direct feedlot-to-meatpacker sales of 900 to 1100 pound steers for four U.S. regions are used in the analysis. The four regions are: Iowa and Southern Minnesota, Eastern Nebraska, Western Kansas, and Texas. Prices for these regions were gathered from the USDA's weekly LS-214 publication. Direct sales quotes are used because these prices reflect the actual offers made by the order buyers of meatpackers. The wholesale price used to calculate the margins is the USDA daily boxed beef cutout value series. The price series are converted to a margin by subtracting the live cattle price converted to a carcass equivalent (price/61.5%) from the boxed beef cutout value.\(^2\)

The supply is formulated as a linear function influenced by factors affecting the future profitability of feeding and seasonal factors. The daily closing price of the nearby corn futures and

\(^2\)Ward (1988) suggests the proportion of meat to live animal weight is 61.5% or \( l/k = 0.615 \).
feeder cattle futures contracts and a daily interest rate are used to reflect the future profitability of feeding. The seasonal components are sets of dummy variables on days of the week, the fourth week in the month, and the season of the year. In many market regions, transactions are heaviest early in the week. Further, the supply from feedlots may be different during the fourth week of the month as operators prepare to meet cash demand of billings commonly faced on the first of each month. The seasonal dummies are used to capture the live cattle supply fluctuations that occur in the spring and fall due to the fluctuations of the calf crop.

Use of the noncooperative game theoretic model requires that the industry be relatively stable over time. Specifically, the parameters of the cost and demand functions should be stable. This temporal stability is necessary because these parameters are not estimated directly. The meatpacking industry does not globally possess this feature. Examining the industry structure from the period 1980 to 1986 indicates that two subperiods of relative stability exist. These are from June, 1980, through June, 1982, and from June, 1984, through June, 1986. These data periods are used in the empirical analysis.

Table 1 presents the likelihood ratio test statistics for the presence of the trigger pricing strategies in the margin models.\textsuperscript{3} Table 2 presents the conjectures, proportional shift parameters, and probabilities of observing cooperation related to market power. The main result of the analysis is that market power appears to be exercised in both sample periods in the four markets. From Table 2, it is seen that the proportional shift parameters are similar in size between markets within each sample period. The noncooperative regime margin levels are between 59.6\% and 63.1\% of the cooperative regime margin level in the first sample, and between 46.6\% and 58.7\% in the second sample period.

Based on the number of large meatpackers in each market, the conjectures were calculated [equation (17)]. The estimated conjectures increased modestly between the two periods, between $0.10/$cwt and $0.13/$cwt of the live animal price in the first period and between $0.13/$cwt and $0.15/$cwt in the second period. In general, these estimates are smaller than conjectures estimated

\footnote{The estimated margin models, corrected for autocorrelation, are not presented due to space limitations.}
in other studies. The conjectures here are 0.15% to 0.23% of the live animal price; previous research which measured conjectures in more long-run and aggregate frameworks found conjectures for meatpackers between 1% to 2.5% of cattle prices (Connor 1989; Quail, et al; Schroeter; Ward 1982).

The estimates of the probability of cooperation ($\lambda$) vary considerably across markets and time periods, but on balance decline between the two periods. The probability of observing cooperation in the Corn Belt markets of Iowa and Eastern Nebraska in the first period was 0.43 and 0.58, respectively. These markets experienced rather dramatic declines in the probability of cooperation in the second period. Both Texas and Western Kansas experienced lower probabilities of cooperation during the first period, 0.26 and 0.20, respectively. However, these figures only declined marginally in the second period. The changes in the probability of observing cooperation between the two periods suggests a reduction in the exercise of market power.

An overall measure of the market power exercised, the expected gains from cooperation, can be developed by combining the conjectures and the probability of cooperation estimates (18)-(21). Figure 1 provides information on total regional expected gains to cooperation and the average weekly volume of cattle marketed for each of the four markets during the two periods. Figure 2 provides expected gains on a per head basis. Overall, the results suggest a reduction in the exercise of market power between the two periods. The most notable differences in expected gains and the expected gains per head between the periods appear in the Iowa and E. Nebraska markets. Less dramatic differences in market power are evidenced in the per head gains in W. Kansas and Texas. In the Texas market, the increase in volume during the second period results in an overall increase in total expected gains from cooperation. However, in the W. Kansas market the total expected gains in the second period decline as the increase in volume in the second period does not offset the decline the gains on a per head basis. The largest reductions in gains experienced in the Corn Belt markets of Iowa and E. Nebraska are consistent with reductions or stability in cattle numbers. Overall, during the second period, the Corn Belt regions faced large reductions in fed cattle marketings, suggesting that the existence of excess capacity may have inhibited the ability of
meatpackers to exercise market power. The reasons for the reduction in market power in the W. Kansas and Texas markets are less clear, but could reflect the close spatial price linkages that exist among these markets and their influence on the ability of meatpackers to exercise oligopsonistic power.

Conclusions

The primary conclusion of the analysis is that oligopsonistic market power was exercised in all the markets for both time periods. The behavior associated with the noncooperative pricing through a trigger price strategy appears to emerge in daily packer margins and market prices for live cattle. However, the nature of the conduct differs among the markets and changes over time as do the expected gains from cooperation. Estimated conjectures increased modestly in the second period, but the time the meatpackers were in the cooperative state declined. The overall exercise of market power appears to have declined across the two periods. The most dramatic declines in market power were found in the Corn Belt markets which experienced reductions in cattle numbers and may have resulted in more competitive pricing due to excess plant capacity. The less dramatic decline in market power in the W. Kansas and Texas markets may be attributable to the spatial price linkages that exist among these markets.

The results of the analysis suggest the need to monitor conduct in the meatpacking industry as well as its structure. Meatpacker conduct can vary in live cattle markets for different time periods and different markets. While the actual exercise of market power may have declined in the more recent period, monitoring of cattle industry may still be important, in particular, during periods of increased supplies relative to packing plant capacity.
Table 1. Likelihood Ratio Tests for the Presence of the Bernoulli Switching Regression Model with Serial Correlation Versus the Null Hypothesis of a linear Model of Margins Corrected for Serial Correlation.

<table>
<thead>
<tr>
<th>Market</th>
<th>First Period: 5/80-9/82</th>
<th>Second Period: 7/84-7/86</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test Statistic&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Prob &gt;χ&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Iowa</td>
<td>13.3080</td>
<td>0.0003</td>
</tr>
<tr>
<td>Eastern Nebraska</td>
<td>31.2840</td>
<td>0.0001</td>
</tr>
<tr>
<td>Western Kansas</td>
<td>30.7270</td>
<td>0.0001</td>
</tr>
<tr>
<td>Texas-New Mexico</td>
<td>16.8600</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

<sup>a</sup>Test statistics are distributed χ<sup>2</sup> with one degree of freedom.

Table 2. Summary of Parameter Estimates and Standard Errors from the Bernoulli Models Corrected for Serial Correlation Including the Market Conjectures, Proportional Shift Parameters, and the Probability of Observing the Cooperative Regime.

<table>
<thead>
<tr>
<th>Market</th>
<th>First Period: 5/80-9/82</th>
<th>Second Period: 7/84-7/86</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β&lt;sub&gt;0&lt;/sub&gt;</td>
<td>φ</td>
</tr>
<tr>
<td>Iowa</td>
<td>0.1255**</td>
<td>0.6234**</td>
</tr>
<tr>
<td>Eastern Nebraska</td>
<td>0.1327**</td>
<td>0.6018**</td>
</tr>
<tr>
<td>Western Kansas</td>
<td>0.1009**</td>
<td>0.5962**</td>
</tr>
<tr>
<td>Texas-New Mexico</td>
<td>0.1229**</td>
<td>0.6313**</td>
</tr>
<tr>
<td></td>
<td>β&lt;sub&gt;0&lt;/sub&gt;</td>
<td>φ</td>
</tr>
<tr>
<td>Iowa</td>
<td>0.1504**</td>
<td>0.5488**</td>
</tr>
<tr>
<td>Eastern Nebraska</td>
<td>0.1371**</td>
<td>0.5887**</td>
</tr>
<tr>
<td>Western Kansas</td>
<td>0.1336**</td>
<td>0.4657**</td>
</tr>
<tr>
<td>Texas-New Mexico</td>
<td>0.1377**</td>
<td>0.5870**</td>
</tr>
</tbody>
</table>

A double asterisk indicates significance at the 1% level and a single asterisk indicates significance at the 5% level.
Figure 1: Expected Gains to Cooperation and Volumes Traded

![Chart showing expected gains and volumes traded for different regions.](image)

- **First Period Gains**
- **Second Period Gains**
- **First Period Volume**
- **Second Period Volume**

Figure 2: Expected Per Head Gains to Cooperation

![Chart showing expected per head gains for different regions.](image)

- **First Period**
- **Second Period**
REFERENCES


