COINTEGRATION, ERROR CORRECTION, AND THE MEASUREMENT OF OLIGOPSONY CONDUCT IN THE U.S. CATTLE MARKET

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Selected paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, 24-27 July 2005

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Abstract: US cattle producers often claim that cattle prices are below competitive levels. In this paper, short-run and long-run oligopsony conduct is estimated by utilizing an oligopsony dynamic model. Results of time-series analysis indicate that the hypothesis of competitive conduct in the short-run and in the long-run cannot be rejected.

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1.1 Introduction

Cattle producers often claim that, because four beef-packers slaughter more than 80 percent of the cattle in the United States, cattle prices are below what they should be had the industry been less concentrated. However, preponderance of econometric evidence suggests that, although cattle prices are below their competitive level, the difference is often not big enough to warrant concern.

Most of the evidence is forthcoming from research along the lines of what is called the New Empirical Industrial Organization, where market power is treated as a parameter to be estimated from single industry time-series data, rather than something to be measured from accounting data as used to be the case in past cross-industry studies. When using time-series data, however, presence of non-stationarity and co-integration of variables renders conventional significance unreliable, leading to erroneous inference about industry conduct. Since none of the past studies of the beef-packing industry considered the properties of the time series before estimation of oligopsony conduct, it remains to be seen whether the finding of benign market power in the industry still hold when more appropriate econometric techniques are used. In this paper, oligopsony conduct is estimated by adapting to the oligopsony case the dynamic oligopoly model proposed by Steen and Salvanes (1999). Their model is a reformulation of Bresnahan's (1982) oligopoly model within an error correction framework.

Using quarterly data for the 1970-2002 periods, the hypothesis of competitive conduct in the short-run and in the long-run cannot be rejected. The short-run estimate of oligopsony conduct is 0.0012064 and the long-run estimate is 0.00523. Both are not statistically different from zero at the 5% level of significance. The results represent another piece of econometric evidence pointing to competitive conduct in the beef-packing industry despite increased levels of concentration.

One particular aspect is rising concentration in the beef-packing industry and its effect on live cattle prices. Data from the U.S. Department of Agriculture's Grain Inspection Packers and Stockyards Administration (USDA-GIPSA) show that both the number and the size distribution of beefpacking plants changed dramatically in the recent years. Between 1980 and 1999 the number of plants decreased from 704 to 204, and the share of the top four firm in steer and heifer slaughter increased from 35.7 percent to 80.6 percent, and Herfindahl-Hirshman Index (HHI) of concentration rose from 561 to 1920.

According the Department of Justice Merger Guidelines, an industry with HHI exceeding 1800 is considered highly concentrated. Preponderance of evidence while the beef-packing industry exerts some degree of market power when procuring live cattle, that degree, according to some, is not large enough to warrant concern. Others argue that, given the large volume of cattle slaughtered every year, even a small degree of market power can translate into large transfers from the cattle producers to beef-packers. Yet others note that losses to cattle producers are more than offset by the cost savings generated by increased concentration in the beef-packing industry. More importantly, as more slaughter cattle is now procured through contracts, otherwise know as captive supplies, there is also concern that packers may also "manipulate" cash prices to influence the base price used to negotiate contracts. Granted that there is merit to each of the preceding arguments, all of them hang to a large degree on the academic research that guides them. The issue, however, is that the use of time series in estimation of market power poses special problems for inference when data are non-stationary and co-integrated. In that case, use of conventional significance tests may lead one to erroneously reject or fail to reject competitive conduct. So far none of the studies of beef-packing conduct has taken advantage of advances in times series analysis to mitigate the mentioned problems. So, it remains to be seen whether past conclusions of benign market power in the industry still hold when the inference problems due to non-stationarity and co-integration are resolved.

1.2 Objective of the Study

In light of the preceding, the purpose of this research is to revisit the econometric problem of estimating the degree of beef-packer oligopsony conduct in spot markets. The contribution of this study is that it takes into account dynamics elements of the industry. The most common motivation for a dynamic approach is the statistical importance of accounting for short-run dynamics in the data, and solving the inference problem when using non-stationary data.

The modeling framework adapts Steen and Salvanes (1999) dynamic oligopoly model to oligopsony. Shifts in livestock supply are used to identify short- and long- run indices of oligopsony conduct in beef-packing using an error correction framework. The model allows for short-run departures from long-run equilibrium in the data. These short-run deviations might be caused by factors such as random shocks, contracts, seasonal shifts etc., and by including lagged observations of the endogenous variables, we take into account dynamic factors, which cannot be included in static models.

Thus, the error correction model framework provides a solution both to statistical problems generated by short-run dynamics and stationarity in the data that make static models inadequate.

2. LITERATURE REVIEW

Several studies have investigated the exercise of market power in the beef packing industry. Azzam and Schroeter (1991), in their paper “Implications of Increased Regional Concentration and Oligopsonistic Coordination in the Beef Packing Industry” used a simple calibration/ stimulation model to gage potential dangers of increased concentration and oligopsonistic coordination. In their study findings were not as alarming as findings of conventional econometric studies. The authors concluded that even perfect collusion in regional cattle market would depress price by only about one percent and reduce slaughter volume by only about one and a half percent.

Azzam and Schroeter (1995) extended the foregoing model to analyze a problem first asserted by Williamson (1968): the market power/cost efficiency tradeoff in horizontal consolidation. Plant closings and acquisitions in beef packing may occur because of the potential improvement in plant utilization or cost efficiencies due to multi-plant operation. However, consolidation of production in larger, more efficient plants, or reorganization bringing existing plants under more unified control increases the concentration and may lead to greater market power. The economic issue was whether or not the cost reductions achieved through economies of plant size or multi-plant operation offset allocative inefficiency resulting from increased market power. Findings showed that a reduction in marginal processing cost of 2.4 percent more than offset social welfare losses from market power stemming from a 50 percent increase in concentration and average plant size. The cost reduction actually achieved from a 50 percent increase in average plant size is about 4 percent.

Using a method that allows market conduct to vary over time, Azzam and Park (1993), in their paper "Testing for Switching Market Conduct" adapted Bresnahan's (1982) model to oligopsony rather than oligopoly, and found out that, beginning in 1977, conduct in the beef industry underwent a transition from competitive to modestly oligopsonistic. Results were based on annual data from 1960 to 1987.

Koontz, Garcia and Hudson (1993) in their paper "Meat-Packer Conduct in Fed Cattle Pricing: An Investigation Of Oligopsony Power", assessed the degree of oligopsony power exercised by beef packers through examination of day to day movements in regional beef margin, by using the trigger-price model of "non-cooperative collusion" developed by Green and Porter (1994). They applied the technique to daily beef margin data from each of four supply regions – Iowa, Eastern Nebraska, Western Kansas, and Texas-New Mexico- for each of two times periods: May 1980 to September 1982 and July 1984 to July 1986. Findings suggest beefpacker oligopsony alternated between periods of cooperative and non-cooperative pricing conduct. Beef packers were not successful in sustaining effective cooperation.

Stiegert, Azzam and Brorsen (1993), in their paper "Markdown Pricing and Cattle Supply in the Beef Packing Industry", explored the possibility that beefpacker conduct may be consistent with cattle pricing being determined adherence an average cost based rule. Their results showed that average cost pricing of cattle was the rule during periods of expected shortfalls in cattle supply. Shortfalls induced packers to increase the markdowns, apparently to insure a margin adequate to cover processing costs resulting from inadequate cattle supply. Estimates were based on quarterly data from 1972 through 1986.

None of the past studies, however, considered the problem of non-stationarity that makes statistical inference unreliable as well as the inclusion of dynamic factors that make static models inadequate for estimation of oligopsony conduct.

Steen and Salvanes, in their paper (1999) "Testing for Market Power Using a Dynamic Oligopoly Model", were the first to derive a dynamic reformulation of Bresnahan's (1982) oligopoly model in an error correction framework, and apply to the estimation of short- and long-run oligopoly conduct. Applied to the French salmon market, results suggest the salmon market to be competitive in the long-run, but indicate that Norway has some market power in the short-run.

3. CONCEPTUAL MODEL FOR IDENTIFYING OLIGOPSONY CONDUCT

3.1 Theoretical specification

Assuming the production relationship between processed beef and live cattle is of fixed proportions, both cattle and the beef can be denoted by the same variable Q. The supply function of live cattle is given by:

$$Q = f(P, Z; \alpha) + \eta, \quad (1)$$

where Q is quantity of live cattle, P is supply price; Z is a vector of exogenous variables affecting supply. The vector α denotes the parameters to be estimated, and η is an error term.

Assuming, for simplicity, the supply function, takes the linear form:

$$Q = \alpha_1 + \alpha_p P + \alpha_z Z + \eta, \tag{2}$$

its inverse is given by:

$$P = (Q - \alpha_1 - \alpha_z Z - \eta) / \alpha_p.$$

Given P, packer total expenditures (TE) on livestock are denoted by:

$$TE = P * Q = (Q^2 - \alpha_1 Q - \alpha_z Z Q - \eta Q) / \alpha_p,$$

and marginal expenditures by:

$$ME = P + (Q / \alpha_p). \tag{3}$$

In addition to expenditures on livestock, packers incur processing costs (C):

$$C = \mathcal{g}(Q, W; \beta),$$

where W is a vector of exogenous factor prices, and β is a vector of parameters.

Assuming packers are price takers in the wholesale beef, equilibrium in the live cattle market is given by:

$$ME = NMVP, \tag{4}$$

where $NMVP = P_W - C_Q$ is the marginal value product of the cattle net of processing cost, P_W is the price of the processed beef, and C_Q is marginal processing cost assumed, for simplicity, to take the linear form:

$$C_Q = \beta_1 + \beta_Q Q + \beta_W W + v_t, \tag{5}$$

where v_t is an error term.

Substituting from equation (3) and (5) into (4) yields:

$$P + (Q/\alpha_p) = P_W - C_Q, \tag{6}$$

or $$(P_W - P - C_Q)/P_W = (Q/\alpha_p),$$

which is the Lerner index for a pure monopsonist.

For empirical implementation, it is more convenient to rewrite (6) as:

$$M = \lambda(Q/\alpha_p) + \beta_1 + \beta_Q Q + \beta_W W, \tag{7}$$

where M is the farm-wholesale price spread, and λ is a summary statistic measuring oligopsony power. Under perfect competition, $\lambda=0$ and the margin equals marginal processing cost. When $\lambda=1$, collusive oligopsony. When $0 < \lambda < 1$ various oligopsony regimes apply. The econometric problem is to estimate λ along with the rest of the parameters in (7).

The starting point is to rewrite (7) as:

$$M = \beta_1 + \delta Q + \beta_W W,$$

where $\delta = (\lambda/\alpha_p) + \beta_Q$. However, since δ is a composite of λ and β_Q, it is not possible to determine them separately from knowledge of δ.

Figure 1 can illustrate the problem. The initial equilibrium in the live cattle market, given by point 'a', is consistent with both perfect competition, where S1 intersects with VMPc, and oligopsony, where ME1 intersects VMPm. Suppose an exogenous shock causes a parallel shift in the supply curve from S1 to S2. Although the equilibrium moves from 'a' to 'b', competition and oligopsony are not distinct.

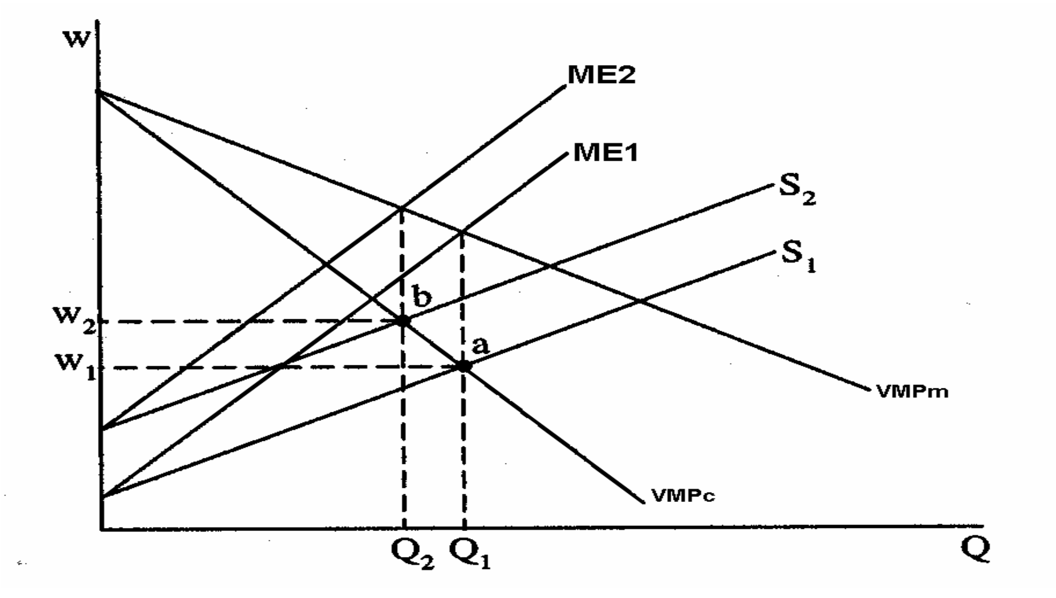


Figure 1. Market Power not Identified

The problem is solved by introducing elements both of rotation and of vertical shifts in the supply curve (Figure 2). In figure 2, this is indicated by the shift and rotation from S1 to S2. Under perfect competition the equilibrium moves from ‘a’ to ‘b’ tracing out the derived demand curve VMPc. On the other hand, under oligopsony the equilibrium moves from ‘a’ to ‘c’. Thus, when one shifts as well as rotates the supply curve, the hypothesis of perfect competition and oligopsony are distinct.

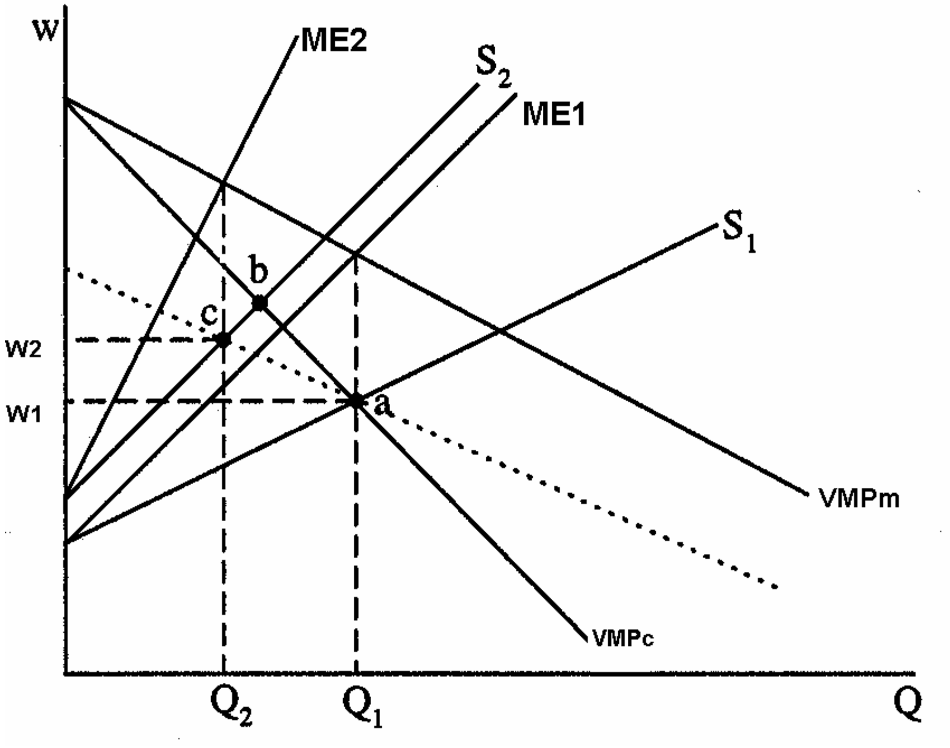


Figure 2. Market Power Identified

The revised oligopoly with rotation and shift of the supply function is presented next.

3.2 The Static Version

Let the supply curve for live cattle at time t be given by:

$$Q_t = \alpha_1 + \alpha_p P_t + \alpha_z Z_t + \alpha_{pz} P_t Z_t + \eta_t, \qquad (8)$$

where, again Z is a vector of exogenous variables, which interact with P.

Since the marginal processing cost for the packers at time t is given by:

$$C_t = \beta_1 + \beta_Q Q_t + \beta_W W_t + \nu_t,$$

profit maximization now yields the new margin relation:

$$M = \lambda Q^* + \beta_1 + \beta_Q Q + \beta_W W + \nu \tag{9}$$

where $Q^* = [Q/(\alpha_p + \alpha_{pz} Z)]$

The parameter λ is identified by first estimating the supply equation (8), and using the estimator of α_p and α_{pz} to construct Q^*. However, estimation of (8) and (9) as they are, ignores the possibility of non-stationary time series as well as the existence of dynamic factors. All these elements might make the static model unreliable and inadequate for estimating the degree of oligopsony power.

3.3 The Dynamic Version

The most common motivation for a dynamic approach is the statistical importance of accounting for short-run dynamics in the data, and solving the inference problem when using non-stationary data.

The error correction model framework allows for short-run departures from long-run equilibrium in the data, and by including lagged observations of the endogenous (dependent) variables we take into account the importance of dynamic factors, the effects of which mean that adjustment from one equilibrium to the another generally takes place over a (sometimes extended) period of time. The absence of these dynamic factors from static models might make them inadequate.

The standard approach to dealing with non-stationary time series has been to difference them as many times as needed to make them stationary. Once all series have been transformed to stationary, regression models can be applied and standard asymptotic inferences can be obtained. The problem with this approach is that differencing eliminates the long-run information contained in the levels of the variables.

Another point to note is that if co-integrated I (d) variables are being used in a Vector Auto Regressive (VAR) model, setting up a model solely in terms of differences and lags of the differences (to capture dynamics) is a misspecification. The correct specification is one that includes an error correction mechanism.

The next section shows, how the error correction model (ECM) formulation relates to the Autoregressive Distributed Lag (ADL) model for the oligopsony framework used in this study. In particular, it will be shown that the parameters representing the stationary long-run solution of the ADL model are the same as the long-run parameters found directly in an ECM model.

3.3.a The Live Cattle Supply Function

When the supply function, as given by (8), is parameterized by an ADL form with one lag and without an intercept term, it becomes:

$$Q_t=\alpha_{p0}P_t+\alpha_{p1}P_{t-1}+\alpha_{z0}Z_t+\alpha_{z1}Z_{t-1}+\alpha_{pz0}P_tZ_t+\alpha_{pz1}P_{t-1}Z_{t-1}+$$
$$+\alpha_{Q1}Q_{t-1}+\eta_t \qquad (10)$$

The short-run parameters are the coefficients on the contemporaneous variables, i.e. α_{p0}, α_{z0} and α_{pz0}. Since the long-run stationary equilibrium implies: $Q = Q_t = Q_{t-1}$, $P = P_t = P_{t-1}$, $Z = Z_t = Z_{t-1}$ and $PZ = P_tZ_t = P_{t-1}Z_{t-1}$, the ADL supply equation can be rewritten as:

$$Q =[(\alpha_{p0}+\alpha_{p1})/(1-\alpha_{Q1})]P+[(\alpha_{z0}+\alpha_{z1})/(1-\alpha_{Q1})]Z$$
$$+[(\alpha_{pz0}+\alpha_{pz1})/(1- \alpha_{Q1})] PZ. \qquad (11)$$

The long-run stationary solution is characterized by three long-run parameters, represented by the three brackets in (11). To see this, add and delete Q_{t-1}, $\alpha_{p0}P_{t-1}$, $\alpha_{z0}Z_{t-1}$, and $\alpha_{pz0}P_{t-1}Z_{t-1}$ on the right hand side of (10). The resulting supply function

$$Q_t=\alpha_{p0}P_t+\alpha_{p1}P_{t-1}+\alpha_{z0}Z_t+\alpha_{z1}Z_{t-1}+\alpha_{pz0}P_tZ_t+\alpha_{pz1}P_{t-1}Z_{t-1}$$
$$+\alpha_{Q1}Q_{t-1}+(Q_{t-1}+\alpha_{p0}P_{t-1}+\alpha_{z0}Z_{t-1}+\alpha_{pz0}P_{t-1}Z_{t-1}) -Q_{t-1}-\alpha_{p0}P_{t-1}-\alpha_{z0}Z_{t-1}$$
$$- \alpha_{pz0}P_{t-1}Z_{t-1} + \eta_t,$$

can be rearranged as:

$$Q_t-Q_{t-1} = (\alpha_{p0}P_t-\alpha_{p0}P_{t-1}) + (\alpha_{p0}P_{t-1}+\alpha_{p1}P_{t-1})+$$
$$+(\alpha_{z0}Z_t-\alpha_{z0}Z_{t-1}) +(\alpha_{z0}Z_{t-1}+\alpha_{z1}Z_{t-1})+$$

$$+(\alpha_{pz0}P_tZ_t-\alpha_{pz0}P_{t-1}Z_{t-1}) + (\alpha_{pz0}P_{t-1}Z_{t-1}+\alpha_{pz1}P_{t-1}Z_{t-1})+$$

$$+(\alpha_{Q1}Q_{t-1}-Q_{t-1})+\eta_t.$$

or, using the difference operator:

$$\Delta Q_t=\alpha_{p0}\Delta P_t+(\alpha_{p0}+\alpha_{P1})P_{t-1}+\alpha_{z0}\Delta Z_t+(\alpha_{z0}+\alpha_{z1})Z_{t-1}+\alpha_{PZ0}\Delta P_tZ_t$$

$$+(\alpha_{PZO}+\alpha_{PZ1})P_{t-1}Z_{t-1}+(\alpha_{Q1}-1)Q_{t-1}+\eta_t,$$

where Δ is the difference operator.

The error correction representation of the above equation is:

$$\Delta Q_t=\alpha_{P0}\Delta P_t+\alpha_{z0}\Delta Z_t+\alpha_{PZ0}\Delta P_tZ_t+$$

$$+(1-\alpha_{Q1})\{Q_{t-1}-[(\alpha_{P0}+\alpha_{P1})/(1-\alpha_{Q1})]P_{t-1}-[(\alpha_{z0}+\alpha_{z1})/(1-\alpha_{Q1})]Z_{t-1}+$$

$$+[(\alpha_{PZO}+\alpha_{PZ1})/(1-\alpha_{Q1})]\,P_{t-1}Z_{t-1}\}+\eta_t. \qquad (12)$$

Adding an intercept term, and letting $\gamma=1-\alpha_{Q1}$, $\alpha^*_j=\alpha_{j0}+\alpha_{j1}$ for j=P, Z, PZ, and k>1, equation (12) is written as:

$$\Delta Q_t=\alpha_1+\alpha_{Q,i}\sum_{i=1}^{k-1}\Delta Q_{t-i}+\alpha_{P,i}\sum_{i=0}^{k-1}\Delta P_{t-i}+\alpha_{z,i}\sum_{i=0}^{k-1}\Delta Z_{t-i}+$$

$$+\alpha_{PZ,i}\sum_{i=0}^{k-1}\Delta(P_{t-i}Z_{t-i})+\gamma\,(Q_{t-k}-\theta_pP_{t-k}-\theta_zZ_{t-k}-\theta_{pz}P_tZ_{t-k})+\eta_t,$$

where

$$\theta_P = \alpha^*_P/\gamma,\ \theta_Z = \alpha^*_Z/\gamma,\ \theta_{pz} = \alpha^*_{PZ}/\gamma.$$

The summations capture the short-run dynamics parameters. The terms in brackets are the error correction model terms, which capture the stationary long-run relationship. Thus, the parameter θ_P measures the stationary (if there is cointegration) long-run impact of P on Q. The parameter γ captures the impact of ΔQ_t being away from the long-run target. This approach accounts for autocorrelation and non-stationarity. Assuming that the variables are stationary in their first differences, all the summations are stationary and, if the variables are co-integrated, the linear combination in the parenthesis is stationary.

3.3.b The Margin Relation:

To identify oligopsony conduct in the short-run (λ_0) and in the long-run (Λ), we reformulate equation (9) using the error correcting model framework. Proceeding first with an ADL form with one lag and without an intercept term equation (9) becomes:

$$M = \beta_{Q0} Q_t + \beta_{Q1} Q_{t-1} + \beta_{w0} W + \beta_{w1} W_{t-1} + \lambda_0 Q^*_t + \lambda_1 Q^*_{t-1} + \beta_{M1} M_{t-1} + \nu_t \quad (13)$$

where Q^* is calculated using the long-run parameters from (12), i.e.,

$$Q^* = Q_t / (\theta_P + \theta_{PZ} Z),$$

or

$$Q^* = Q_t \,/\, \{[(\alpha_{P0}+\alpha_{P1}) \,/\, (1-\alpha_{Q1})] + [(\alpha_{PZO}+\alpha_{PZ1})/(1-\alpha_{Q1})]\ Z\}.$$

The short-run parameters are the coefficients on the contemporaneous variables, i.e. β_{Q0}, β_{W0} and λ_0. The long-run stationary solution is found when $M=M_t=M_{t-1}$, $Q=Q_t=Q_{t-1}$, $W=W_t=W_{t-1}$ and $Q=Q^*_t=Q^*_{t-1}$.

The ADL relationship equation in (13) then becomes:

$$M = [(\beta_{Q0}+\beta_{Q1})/(1-\beta_{M1})]\ Q+[(\beta_{W0}+\beta_{W1})/(1-\beta_{M1})]\ W+$$

$$+[(\lambda_{Q^*0}+\lambda_{Q^*1})/(1-\beta_{M1})]Q^*+\nu_t \qquad (14)$$

The long-run solution is characterized by three long-run parameters, represented by the three brackets in (14). This is obtained by adding and deleting M_{t-1}, $\beta_{Q0}Q_{t-1}$, $\beta_{W0}W_{t-1}$, and $\lambda_{Q^*0}Q^*_{t-1}$ on the right hand side of (14) and then rearranging a manner similar to the supply function.

This yields:

$$\Delta M_t=\beta_{Q0}\,\Delta Q_t+\beta_{W0}\,\Delta W_t+\lambda_0\Delta Q^*_t+$$

$$+(1-\beta_{M1})\Big\{M_{t-1}-[(\beta_{Q0}+\beta_{Q1})/(1-\beta_{M1})]Q_{t-1}-[(\beta_{W0}+\beta_{W1})/(1-\beta_{M1})]W_{t-1}$$

$$+[(\lambda_0+\lambda_1)/(1-\beta_{M1})]Q^*_{t-1}\Big\}+\nu_t. \qquad (15)$$

The short run parameters are the same as in the ADL model, but are now the coefficients on the contemporaneous differenced variables β_{Q0}, β_{W0} and λ_0. The long-run parameters are the terms in the brackets.

By adding an intercept term, denoting $\phi=1-\beta_{M1}$, $\beta^*_j=\beta_{j0}+\beta_{j1}$ for j=Q, W, and letting k >1, equation (15) can be written as:

$$\Delta M_t=\beta_1+\ \beta_{M,i}\sum_{i=1}^{k-1}\ \Delta M_{t-i}\ +\ \beta_{Q,i}\sum_{i=0}^{k-1}\ \Delta Q_{t-i}\ +\ \beta_{W,i}\sum_{i=0}^{k-1}\ \Delta W_{t-i}\ +$$

$$+\sum_{i=0}^{k-1}\ \lambda_i\Delta Q^*_{t-i}+\phi\ (M_{t-k}-\psi_Q Q_{t-k}-\psi_W W_{t-k}-\Lambda Q^*_{t-k})+\nu_t \qquad (16)$$

where

$$\psi_Q=\beta^*_Q/\phi\ ,\psi_W=\beta^*_W/\phi\ ,\ \Lambda=\lambda^*/\phi.$$

The error correction model formulation provides both a short-run estimate (λ_0), and a long-run estimate (Λ) for λ.

4. EMPIRICAL MODEL AND RESULTS

The estimating model with error correction consists of the live cattle supply equation:

$$\begin{aligned}\Delta Q_t = {} & \alpha_1 + \alpha_{Q,i}\sum_{i=1}^{k-1}\Delta Q_{t-i} + \alpha_{P,i}\sum_{i=0}^{k-1}\Delta P_{t-i} + \alpha_{k,i}\sum_{i=0}^{k-1}\Delta K_{t-i} + \\ & + \alpha_{V,i}\sum_{i=0}^{k-1}\Delta V_{t-i} + \alpha_{Pk,i}\sum_{i=0}^{k-1}\Delta(P_{t-i}K_{t-i}) + \alpha_{PV,i}\sum_{i=0}^{k-1}\Delta(P_{t-i}V_{t-i}) \\ & + \gamma\,(Q_{t-k} - \theta_p P_{t-k} - \theta_k K_{t-k} - \theta_v V_{t-k} - \theta_{pk} P_t K_{t-k} - \theta_{pv} P_t V_{t-k}) \\ & + D2 + D3 + D4 + \eta_t,\end{aligned} \tag{19}$$

and the margin relation:

$$\begin{aligned}\Delta M_t = {} & \beta_1 + \beta_{M,i}\sum_{i=1}^{k-1}\Delta M_{t-i} + \beta_{Q,i}\sum_{i=0}^{k-1}\Delta Q_{t-i} + \beta_{W,i}\sum_{i=0}^{k-1}\Delta W_{t-i} \\ & + \sum_{i=0}^{k-1}\lambda_i \Delta Q^*_{t-i} + \phi(M_{t-k} - \psi_Q Q_{t-k} - \psi_W W_{t-k} - \Lambda Q^*_{t-k}) \\ & + D2 + D3 + D4 + \nu_t.\end{aligned} \tag{20}$$

The dummy variables are added to capture seasonality in live cattle slaughter. The raw data consist of quarterly observations on Q (commercial beef production), P (price of live cattle), K (price of corn), V (price of feeder cattle), M (the farm – wholesale spread), which is the difference between Pw (the wholesale price of beef) and the price of live cattle (P), and W (hourly wage of production workers in meatpacking plants).

The sample starts the first quarter of 1970 and ends the second quarter of 2000. All prices were deflated by the CPI, and the error terms are assumed to have the standard properties.

4.1 The Live Cattle Supply Function

4.1.1 Integration

We test for integration order using Dickey-Fuller's augmented unit root test. Table A in the Appendix contains integration tests for levels and first differences. In levels, for the variable Q, for example, the null hypothesis of non-stationarity without a constant and no trend cannot be rejected at the 10% level. The test statistic of –1.8455 is less (in absolute value) than the critical ADF value of –2.57. The test statistic of 2.037, which is less than the critical value of 3.78, indicates that we cannot reject the null hypothesis that the coefficient of the constant term and the coefficient of the lagged value of Q are statistically different from zero. Again, the hypothesis of non-stationarity with no trend cannot be rejected. When considering the trend, non-stationarity cannot be rejected with and without a constant. Similar test results for non-stationarity were obtained for the rest of the variables: P, K, V, PK, and PV.

In the case of the first difference for the variable Q, the null hypothesis of non-stationarity without a constant and no trend is rejected at the 10% level. The test statistic of –3.126 (in absolute value) exceeds the critical ADF value of –2.57, indicating that non-stationarity can be rejected. The test statistic of 4.8936, which also exceeds the critical value of 3.78 indicates that we can reject the null hypothesis that the coefficient of the constant term and of the lag of the first difference of Q are statistically different from zero. Again, the hypothesis of non-stationarity with no trend can be rejected. When considering the trend, non-stationarity is rejected with and without a constant. Similar test results for non-stationarity were obtained for the rest of the first differences in the rest of the variables.

Since the variables are stationary in the first differences, they will be used such as to specify the model. Since the first differences of the variables in the live cattle supply function are stationary, the left-hand side variable in equation (19) as well as the explanatory variables expressed in the first differences are stationary, this allows us to use OLS in our estimation in order to obtain meaningful parameters. The next step is to check if the variables in the parentheses are co-integrated. If they are then we are certain about the existence of a long-term equilibrium relationship among these variables exists.

4.1.2 Co-integration

We test for co-integration by testing if the regression residuals have a unit root. The results in table B in the Appendix reveal the existence of a co-integrating relationship among Q, P, K, V, PK, and PV at 10% level of significance. As we can see from table B the null hypothesis of no co-integration without a trend is rejected at the 10% level. The test statistic of –48.123 exceeds (in absolute value) than the critical ADF value of –38.4. The test statistic of –5.3435, when considering more than one lags, is more (in absolute value) than the critical value of –4.42, indicating that we can reject the null hypothesis of no co-integration. When considering a trend, no co-integration is also rejected.

4.1.3 Empirical Results

Results for the supply function are presented in table 1. The Akaike's Final Prediction Error was used to determine the lag-length k=1, in order to account for autocorrelation. The implied long-run parameters for constructing Q* are:

θ_P= (-2239.9) / (-0.35352) = 6353.9

θ_{pk} = (1113930) / (-0.35252) = -323187.3

θ_{pv} = (-594.74) / (-0.35252) = 1687.11.

Table 1

OLS Parameter Estimates of the Live Cattle Supply Function (19)

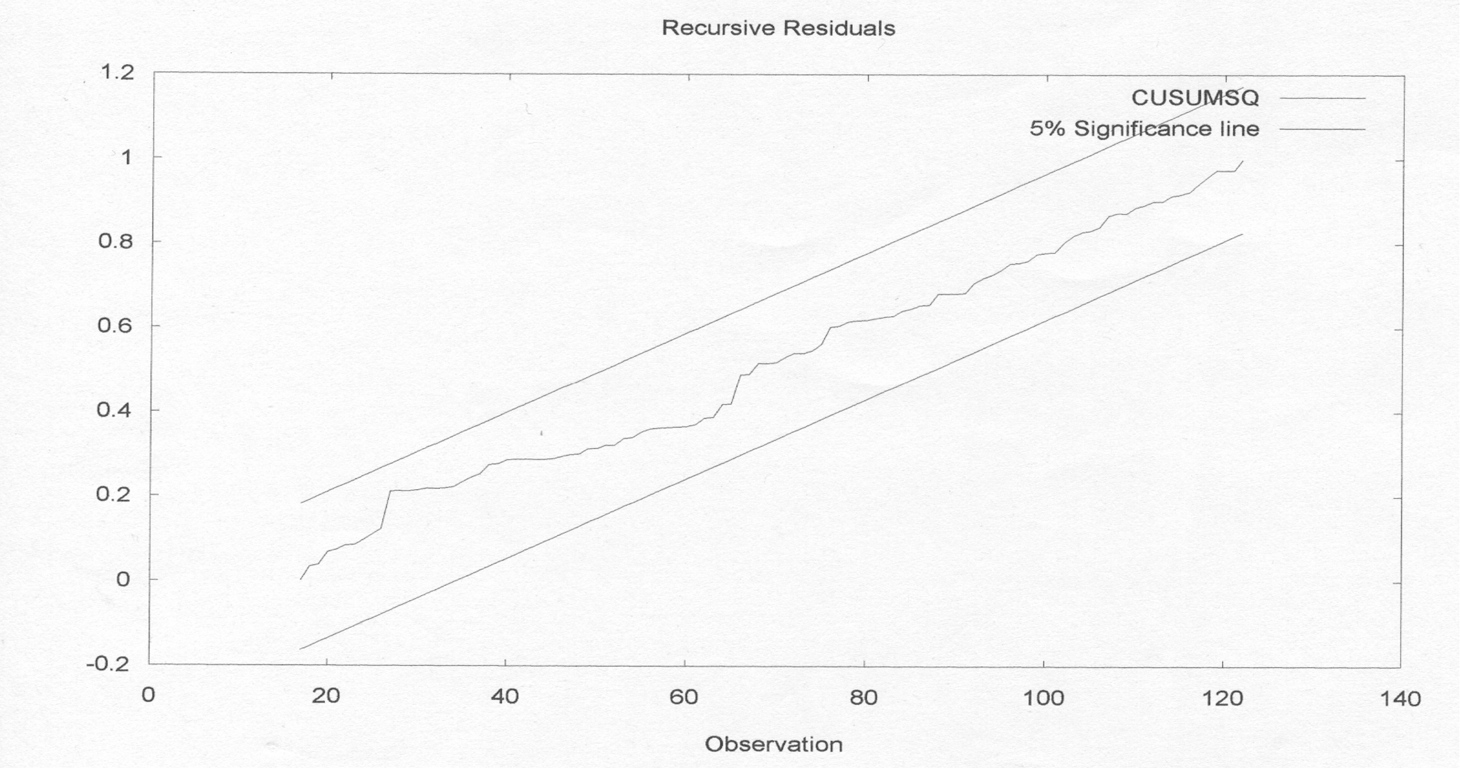
PARAMETER	ESTIMATED COEF.	STAND. ERROR	T-RATIO	P-VALUE
αP,0	-3609.7	999.99	-3.6098	0.0005
αk,0	52734	36100	1.4608	0.147
αV,0	219.85	1999.2	0.10997	0.9126
αPK,0	-81329	59691	-1.3625	0.1759
αPV,0	4290.9	3152.5	1.3611	0.1764
γ	-0.35252	0.672E-02	-5.2421	0
γ θp	-2239.9	623.35	-3.5934	0.0005
γ θk	-27802	21082	-1.3187	0.1901
γ θv	153.7	294.56	0.52178	0.6029
γ θpk	1.14E+05	36492	3.1221	0.0023
γ θpv	-594.74	820.68	-0.7247	0.4702
D2	231.08	39.378	5.8684	0
D3	277.33	41.497	6.6832	0
D4	55.567	41.492	1.3392	0.1834
CONSTANT	2737.3	535.37	5.1128	0

Checking for possible structural change, the CUSUMSQ (figure 3) statistic is consistently within its 5% bounds, while the recursive coefficients of the regressors display no sudden variation as more data is added, indicating that the estimating equation is highly stable and shows no signs of underlying misspecification.

The model was also estimated using 2SLS. The 2SLS estimates were close to those obtained using OLS, the latter are used as basis for the rest of the discussion.

Figure 3

Cumulative Sum of Squared Recursive Residuals of the Cattle Supply Function



4.2 The Margin Relation

4.2.1 Integration

We test for integration order using Dickey-Fuller's augmented unit root test. Table C in the Appendix contains integration tests for levels and first differences. In levels, for the variable M, for example, the null hypothesis of non- stationarity without a constant and no trend cannot be rejected at the 10% level. The test statistic of –1.3296 is less than the critical ADF value of -2.57. The test statistic of 1.1547, which is less than the critical value of 3.78 indicates that we cannot reject the null hypothesis that the coefficient of the constant term and of the lagged value of M are statistically different from zero.

Again, the hypothesis of non-stationarity with no trend cannot be rejected. When considering the trend, non-stationarity cannot be rejected with and without a constant. Similar test results for non-stationarity were obtained for the meatpacking wage (W).

In the case of the first difference of the variable M, the null hypothesis of non-stationarity without a constant and no trend is rejected at the 10% level. The test statistic of –4.7488 is more (in absolute value) than the critical ADF value of –2.57, indicating that non-stationarity can be rejected. The test statistic of 11.283, which exceeds the critical value of 3.78 indicates that we can reject the null hypothesis that the coefficient of the constant term and of the lag of the first difference of Q are statistically different from zero. Again, the hypothesis of non-stationarity with no trend can be rejected. When considering the trend, non-stationarity is rejected with and without a constant. Similar test results for non-stationarity were obtained for the variable W.

4.2.2 Co-integration

We test for co-integration by testing if the regression residuals have a unit root. Results in table D in the Appendix reveal the existence of a co-integrating relationship among M, Q and W at 10% level of significance. The null hypothesis of no co-integration without a trend is rejected at the 10% level. The test statistic of -42.438

exceeds (in absolute value) the critical ADF value of -28.1. The test statistic of -4.763, when considering more than one lag, exceeds (in absolute value) the critical value of -3.81, indicating that the null hypothesis of no co-integration is rejected. When considering a trend, no co-integration is rejected.

4.2.3 Empirical Results

Results for the margin relation are presented in table 2. Akaike's Final Prediction Error was used to decide for the lag-length k=1, in order to account for autocorrelation. Results from 2SLS are also available upon request. Again the CUSUMSQ (figure 4) statistic is consistently within its 5% bounds, and the recursive coefficients of the regressors display no sudden variation as more data is added, indicating that the estimating equation is highly stable and shows no signs of underlying misspecification.

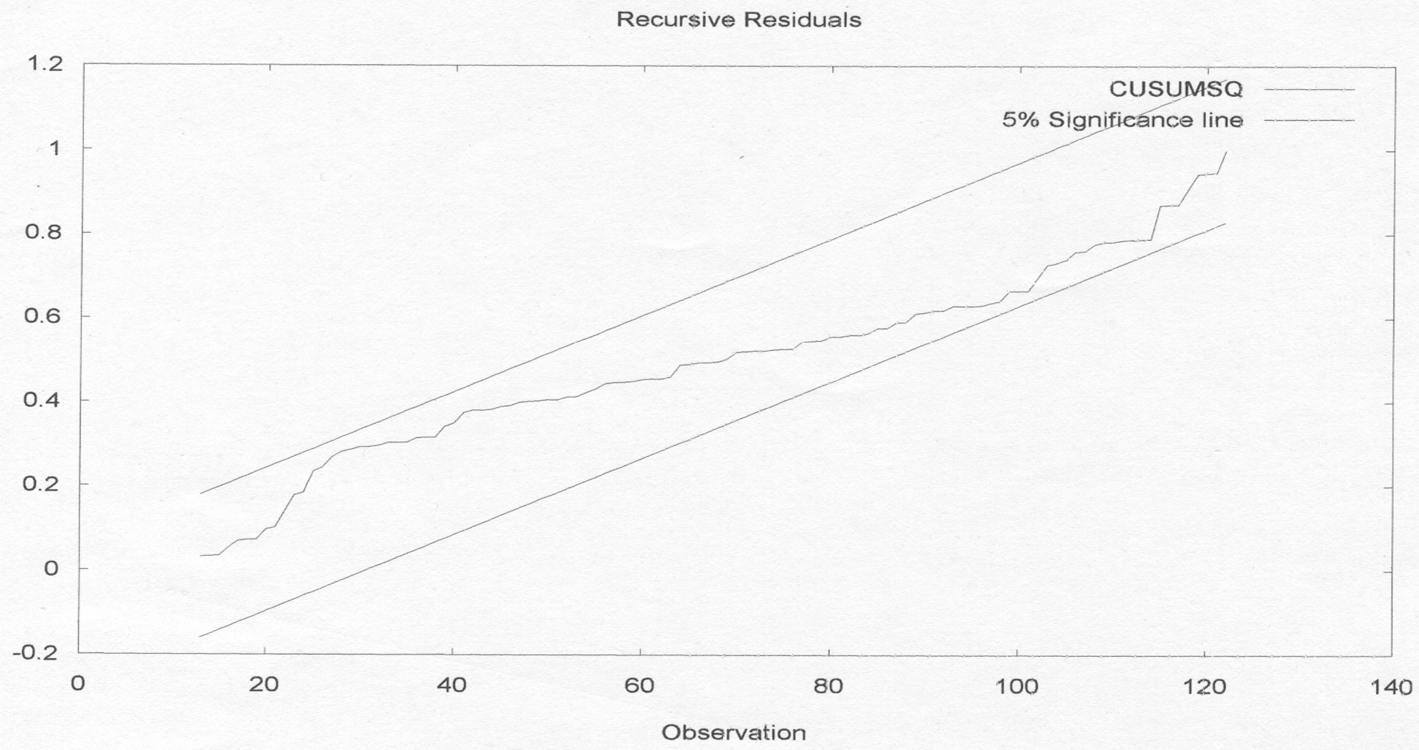
Table 2

OLS Parameter Estimates of the Margin Relation (20)

PARAMETER	**ESTIMATED.COEF.**	**STAND. ERROR**	**T- RATIO**	**P-VALUE**
$\beta W,0$	4.5146	1.9244	2.346	0.0208
$\beta Q,0$	3.2209E-07	0.33195	0.097	0.9229
λ	0.0012064	0.92268	1.3075	0.1938
Φ	-0.32496	0.71287	-4.558	0
$\Phi\psi_w$	1.1325	0.30615	3.6991	0.0003
$\Phi\psi_Q$	-2.2765E-06	0.21044	-1.0818	0.2817
$\Phi\Lambda$	0.0017187	0.90845	1.8919	0.0611
D2	0.0040488	0.19575	2.0683	0.041
D3	0.001808	0.20971	0.86216	0.3905
D4	0.0012536	0.1876	0.66824	0.5054
CONSTANT	0.0022974	0.14279	0.1609	0.8725

Figure 4

Cumulative Sum of Squared Recursive Residuals for the Margin Relation



SUMMARY AND CONCULSIONS

Preponderance of econometric evidence suggests that the highly concentrated beef-packing industry exerts some degree of oligopsony power, although that degree is not large enough to warrant concern. Most the evidence is forthcoming from research along the lines of what called the New Empirical Industrial Organization (NEIO), where market power is treated as a parameter to be inferred from single industry time-series data, rather than something to be measured from accounting data in earlier cross-industry studies.

When using time series, however, presence of non-stationary and co-integration of variables renders conventional significance tests unreliable, and may lead to erroneous inference about market conduct. Since none of the past studies of competition in beef-packing has checked for the properties of the time series before drawing conclusions about conduct in the industry, the question remains open as to whether past findings of benign market power in the cattle market are reliable.

The purpose of this thesis is to revisit the estimation of oligopsony conduct in the US beef-packing sector in spot markets using an error correction model. Oligopsony conduct in the industry is estimated by adapting to the oligopsony case the dynamic oligopoly model of Steen and Salvanes. The contribution of our approach is that by using an error correction framework we account for short-run departures from long-run equilibrium in the data. In cattle markets, these short run deviations might be caused by factors such as random shocks, contracts, seasonal shifts etc., and by including lagged observations of the endogenous variables, we take into account dynamic factors, which cannot be included in static models. Thus, the error correction model provides a solution both to statistical problems generated by short-run dynamics and stationarity in the data as well as important dynamic factors that make static models inadequate.

Using quarterly data for the 1970-2000 period, the hypothesis of competitive conduct in the short-run and in the long-run cannot be rejected. The short-run estimate of oligopsony conduct is 0.0012 and the long-run estimate 0.0052. Both are not statistically different from zero at the 5% level of significance. The results represent another piece of econometric evidence pointing to competitive conduct in the beef packing industry despite increased levels of buyer concentration.

There are two major caveats to the study. First, the behavioral model in this thesis does not consider captive supplies as a decision variable separate from cattle bought on the open market. The second caveat is that the packer decision problem considered in this thesis is static. This ignores the elements of strategic behavior that arise from the repeated interaction between packers in the live cattle market. How that affects the estimate of the degree of oligopsony power in the industry is a question I intend to address in future research.

APPENDIX:

Table A

Results of Augmented Dickey-Fuller Tests for Levels and First Differences in the Cattle Supply Function

1. Tests for Levels

```
  VARIABLE: Q
 DICKEY-FULLER TESTS - NO.LAGS =  10   NO.OBS =  111

    NULL              TEST      ASY. CRITICAL
  HYPOTHESIS        STATISTIC     VALUE 10%
--------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST      -1.8455     -2.57
 A(0)=A(1)=0          2.0237      3.78
                                              AIC =    10.368
                                               SC =    10.661
--------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST      -2.6347     -3.13
 A(0)=A(1)=A(2)=0     2.5823      4.03
 A(1)=A(2)=0          3.5443      5.34
                                              AIC =    10.350
                                               SC =    10.668
--------------------------------------------------------------------
```

```
 VARIABLE : P
 DICKEY-FULLER TESTS - NO.LAGS =   4   NO.OBS =  117

     NULL              TEST      ASY. CRITICAL
  HYPOTHESIS         STATISTIC     VALUE 10%
----------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST       -1.0121     -2.57
 A(0)=A(1)=0          0.88339      3.78
                                              AIC =    -6.310
                                               SC =    -6.168
----------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST       -3.9928     -3.13
 A(0)=A(1)=A(2)=0      5.6524      4.03
 A(1)=A(2)=0           8.0607      5.34
                                              AIC =    -6.420
                                               SC =    -6.255
```

```
VARIABLE : K
 DICKEY-FULLER TESTS - NO.LAGS =   3   NO.OBS =  118

     NULL              TEST      ASY. CRITICAL
  HYPOTHESIS         STATISTIC     VALUE 10%
----------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST       -1.1165     -2.57
 A(0)=A(1)=0          0.88600      3.78
                                              AIC =   -13.533
                                               SC =   -13.416
----------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST       -2.7686     -3.13
 A(0)=A(1)=A(2)=0      2.7996      4.03
 A(1)=A(2)=0           3.9237      5.34
                                              AIC =   -13.573
                                               SC =   -13.432
----------------------------------------------------------------------
 VARIABLE : V
 DICKEY-FULLER TESTS - NO.LAGS =  10   NO.OBS =  111

     NULL              TEST      ASY. CRITICAL
  HYPOTHESIS         STATISTIC     VALUE 10%
----------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST       -2.0047     -2.57
 A(0)=A(1)=0           2.3333      3.78
                                              AIC =    -8.016
                                               SC =    -7.723
----------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST       -3.3841     -3.13
 A(0)=A(1)=A(2)=0      4.0984      4.03
```

```
 A(1)=A(2)=0           5.8030      5.34
                                              AIC =    -8.070
                                               SC =    -7.753
```

```
VARIABLE : PK
 DICKEY-FULLER TESTS - NO.LAGS =   6   NO.OBS =  115

     NULL               TEST      ASY. CRITICAL
  HYPOTHESIS          STATISTIC     VALUE 10%
----------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST      -0.88030     -2.57
 A(0)=A(1)=0          0.68537      3.78
                                              AIC =   -13.908
                                               SC =   -13.717
----------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST       -2.9686     -3.13
 A(0)=A(1)=A(2)=0      3.2149      4.03
 A(1)=A(2)=0           4.5045      5.34
                                              AIC =   -13.965
                                               SC =   -13.750
----------------------------------------------------------------------

 VARIABLE : PV
 DICKEY-FULLER TESTS - NO.LAGS =   5   NO.OBS =  116

     NULL               TEST      ASY. CRITICAL
  HYPOTHESIS          STATISTIC     VALUE 10%
----------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST       -1.9228     -2.57
 A(0)=A(1)=0           1.9858      3.78
                                              AIC =    -7.650
                                               SC =    -7.484
----------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST       -3.8851     -3.13
 A(0)=A(1)=A(2)=0      5.1315      4.03
 A(1)=A(2)=0           7.5472      5.34
                                              AIC =    -7.730
                                               SC =    -7.540
----------------------------------------------------------------------
```

2. First Differences

```
 VARIABLE : (1-B) Q
 DICKEY-FULLER TESTS - NO.LAGS =  10   NO.OBS =  110

     NULL               TEST      ASY. CRITICAL
  HYPOTHESIS          STATISTIC     VALUE 10%
----------------------------------------------------------------------
```

```
  CONSTANT, NO TREND
  A(1)=0  T-TEST     -3.1260     -2.57
  A(0)=A(1)=0          4.8936      3.78
                                               AIC =    10.383
                                                SC =    10.678
 ---------------------------------------------------------------------
  CONSTANT, TREND
  A(1)=0  T-TEST     -3.1616     -3.13
  A(0)=A(1)=A(2)=0    3.3793      4.03
  A(1)=A(2)=0          5.0613      5.34
                                               AIC =    10.397
                                                SC =    10.716
 ---------------------------------------------------------------------

  VARIABLE : (1-B) P
  DICKEY-FULLER TESTS - NO.LAGS =   4   NO.OBS =  116

      NULL              TEST      ASY. CRITICAL
   HYPOTHESIS          STATISTIC     VALUE 10%
 ---------------------------------------------------------------------

CONSTANT, NO TREND
  A(1)=0  T-TEST     -5.0484     -2.57
  A(0)=A(1)=0          12.744      3.78
                                               AIC =    -6.297
                                                SC =    -6.154
 ---------------------------------------------------------------------
  CONSTANT, TREND
  A(1)=0  T-TEST     -5.0318     -3.13
  A(0)=A(1)=A(2)=0    8.4564      4.03
  A(1)=A(2)=0          12.684      5.34
                                               AIC =    -6.280
                                                SC =    -6.114
______________________________________________________________________
 VARIABLE : (1-B) K
  DICKEY-FULLER TESTS - NO.LAGS =  10   NO.OBS =  110

      NULL              TEST      ASY. CRITICAL
   HYPOTHESIS          STATISTIC     VALUE 10%
 ---------------------------------------------------------------------
  CONSTANT, NO TREND
  A(1)=0  T-TEST     -3.4897     -2.57
  A(0)=A(1)=0          6.0901      3.78
                                               AIC =   -13.411
                                                SC =   -13.117
 ---------------------------------------------------------------------
  CONSTANT, TREND
  A(1)=0  T-TEST     -3.5234     -3.13
  A(0)=A(1)=A(2)=0    4.1396      4.03
  A(1)=A(2)=0          6.2081      5.34
                                               AIC =   -13.396
                                                SC =   -13.077
 --------------------------------------------------------------------

  VARIABLE : (1-B) V
  DICKEY-FULLER TESTS - NO.LAGS =   6   NO.OBS =  114
```

```
     NULL                 TEST      ASY. CRITICAL
  HYPOTHESIS          STATISTIC     VALUE 10%
----------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST       -4.3088     -2.57
 A(0)=A(1)=0           9.2831      3.78
                                              AIC =    -8.009
                                               SC =    -7.817
----------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST       -4.2816     -3.13
 A(0)=A(1)=A(2)=0      6.1407      4.03
 A(1)=A(2)=0           9.2111      5.34
                                              AIC =    -7.991
                                               SC =    -7.775
```

```
VARIABLE : (1-B) PK
 DICKEY-FULLER TESTS - NO.LAGS =   7   NO.OBS =  113

     NULL                 TEST      ASY. CRITICAL
  HYPOTHESIS          STATISTIC     VALUE 10%
----------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST       -3.8311     -2.57
 A(0)=A(1)=0           7.3396      3.78
                                              AIC =   -13.886
                                               SC =   -13.668
----------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST       -3.8335     -3.13
 A(0)=A(1)=A(2)=0      4.8992      4.03
 A(1)=A(2)=0           7.3481      5.34
                                              AIC =   -13.869
                                               SC =   -13.628
----------------------------------------------------------------------

 VARIABLE : (1-B) PV
 DICKEY-FULLER TESTS - NO.LAGS =   8   NO.OBS =  112

     NULL                 TEST      ASY. CRITICAL
  HYPOTHESIS          STATISTIC     VALUE 10%
----------------------------------------------------------------------
 CONSTANT, NO TREND
 A(1)=0  T-TEST       -3.7674     -2.57
 A(0)=A(1)=0           7.0977      3.78
                                              AIC =    -7.578
                                               SC =    -7.335
----------------------------------------------------------------------
 CONSTANT, TREND
 A(1)=0  T-TEST       -3.7404     -3.13
 A(0)=A(1)=A(2)=0      4.6934      4.03
 A(1)=A(2)=0           7.0391      5.34
                                              AIC =    -7.560
                                               SC =    -7.293
```

Table B

Results of Augmented Dickey-Fuller Test on Co-integration in the Cattle Supply Function

```
COINTEGRATING REGRESSION - CONSTANT, NO TREND   NO.OBS =  122
 REGRESSAND : Q
  R-SQUARE = 0.6493         DURBIN-WATSON = 0.7947
  DICKEY-FULLER TESTS ON RESIDUALS - NO.LAGS =  0   M =  6
                         TEST      ASY. CRITICAL
                       STATISTIC     VALUE 10%
 ---------------------------------------------------------------------
  NO CONSTANT, NO TREND
          Z-TEST       -48.123     -38.4
          T-TEST       -5.3435     -4.42
                                               AIC =    10.550
                                                SC =    10.573
 --------------------------------------------------------------------
 COINTEGRATING REGRESSION - CONSTANT, TREND      NO.OBS =  122
 REGRESSAND : Q
  R-SQUARE = 0.6617         DURBIN-WATSON = 0.8135
  DICKEY-FULLER TESTS ON RESIDUALS - NO.LAGS =  0   M =  6
                         TEST      ASY. CRITICAL
                       STATISTIC     VALUE 10%
  NO CONSTANT, NO TREND
          Z-TEST       -49.899     -43.5
          T-TEST       -5.4866     -4.70
                                               AIC =    10.527
                                                SC =    10.551
```

Table C

Results of Augmented Dickey-Fuller Tests for Levels and First Differences in the Margin Relation

1. Test for Levels

```
      VARIABLE : M
  DICKEY-FULLER TESTS - NO.LAGS =   2   NO.OBS =  119

      NULL               TEST      ASY. CRITICAL
   HYPOTHESIS          STATISTIC     VALUE 10%
 ----------------------------------------------------------------------
  CONSTANT, NO TREND
  A(1)=0  T-TEST       -1.3296     -2.57
  A(0)=A(1)=0           1.1547      3.78
                                               AIC =    -9.815
                                                SC =    -9.721
 ----------------------------------------------------------------------
  CONSTANT, TREND
  A(1)=0  T-TEST       -1.4845     -3.13
  A(0)=A(1)=A(2)=0      1.1516      4.03
  A(1)=A(2)=0           1.4562      5.34
                                               AIC =    -9.808
                                                SC =    -9.691
 ----------------------------------------------------------------------

 VARIABLE : W
  DICKEY-FULLER TESTS - NO.LAGS =   4   NO.OBS =  117

      NULL               TEST      ASY. CRITICAL
   HYPOTHESIS          STATISTIC     VALUE 10%
 ----------------------------------------------------------------------
  CONSTANT, NO TREND
  A(1)=0  T-TEST       -1.0219     -2.57
  A(0)=A(1)=0           1.7452      3.78
                                               AIC =   -16.090
                                                SC =   -15.948
 ----------------------------------------------------------------------

CONSTANT, TREND
  A(1)=0  T-TEST       -1.9171     -3.13
  A(0)=A(1)=A(2)=0      2.1128      4.03
  A(1)=A(2)=0           1.9264      5.34
                                               AIC =   -16.098
                                                SC =   -15.933
```

2. First Differences

```
    VARIABLE : (1-B) M
DICKEY-FULLER TESTS - NO.LAGS =   5   NO.OBS =  115

    NULL               TEST      ASY. CRITICAL
 HYPOTHESIS          STATISTIC     VALUE 10%
----------------------------------------------------------------------
CONSTANT, NO TREND
A(1)=0  T-TEST       -4.7488     -2.57
A(0)=A(1)=0           11.283      3.78
                                             AIC =    -9.796
                                              SC =    -9.629
----------------------------------------------------------------------
CONSTANT, TREND
A(1)=0  T-TEST       -4.8747     -3.13
A(0)=A(1)=A(2)=0      8.0485      4.03
A(1)=A(2)=0           12.066      5.34
                                             AIC =    -9.792
                                              SC =    -9.601
---------------------------------------------------------------------

VARIABLE : (1-B) W
DICKEY-FULLER TESTS - NO.LAGS =   4   NO.OBS =  116

    NULL               TEST      ASY. CRITICAL
 HYPOTHESIS          STATISTIC     VALUE 10%
----------------------------------------------------------------------
CONSTANT, NO TREND
A(1)=0  T-TEST       -2.5653     -2.57
A(0)=A(1)=0           3.3266      3.78
                                             AIC =   -16.075
                                              SC =   -15.933
----------------------------------------------------------------------
CONSTANT, TREND
A(1)=0  T-TEST       -2.5464     -3.13
A(0)=A(1)=A(2)=0      2.2437      4.03
A(1)=A(2)=0           3.3297      5.34
                                             AIC =   -16.059
                                              SC =   -15.893
----------------------------------------------------------------------
```

Table D

Results of Augmented Dickey-Fuller's Test on Co-integration in the Margin Relation

```
COINTEGRATING REGRESSION - CONSTANT, NO TREND   NO.OBS =  121
 REGRESSAND : M
  DICKEY-FULLER TESTS ON RESIDUALS - NO.LAGS =  0   M =  4
                       TEST      ASY. CRITICAL
                     STATISTIC     VALUE 10%
 ----------------------------------------------------------------------
```

```
 NO CONSTANT, NO TREND
         Z-TEST       -42.438     -28.1
         T-TEST       -4.7631     -3.81
                                                  AIC =    -9.822
                                                   SC =    -9.799
---------------------------------------------------------------------
COINTEGRATING REGRESSION - CONSTANT, TREND      NO.OBS =  121
REGRESSAND : M
 DICKEY-FULLER TESTS ON RESIDUALS - NO.LAGS =  0   M =  4

                       TEST      ASY. CRITICAL
                     STATISTIC     VALUE 10%
---------------------------------------------------------------------
 NO CONSTANT, NO TREND
         Z-TEST       -41.364     -33.5
         T-TEST       -4.6437     -4.15
                                                  AIC =    -9.850
                                                   SC =    -9.826
---------------------------------------------------------------------
```

VARIALE DEFINITION

Data were collected from the web pages listed in the bibliography.

Q = Commercial beef production (millions lbs)

P = Price of cattle (cents / retail lbs)

K = Price of corn ($ / bushel)

V = Price of feeder cattle ($/ 100 lbs)

M = Farm – wholesale beef margin (cents / retail lbs)

W = Meatpacking wage ($ / hour)

PK = Interaction term between P an K

PV = Interaction term between P an V

CPI = Consumer price index (base year = 1967)

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