A Partial-Adjustment, Mixed Linear Model of Price Discovery In an Experimental Market for Fed Cattle

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Abstract

The Fed Cattle Market Simulator (FCMS) was developed by a team of researchers at Oklahoma State University to aid in understanding the forces that influence price discovery in the fed cattle market. Participants in the FCMS play the role of feedlot marketing managers and packing plant procurement agents, and trade paper pens of cattle in the experimental market. Previous research with the FCMS has not attempted to capture the dynamic nature of the price discovery process; this paper uses a partial-adjustment approach to accomplish that goal. A mixed linear model is used to accommodate both fixed and random effects in the data. Results show that the transaction price adjusts only sixteen percent on a week-by-week basis to its desired level. As such, the price discovery process in the experimental market is said to be characterized by slow adjustment, due in part to biological lags in the beef supply chain. This result will be useful in enhancing understanding of the real fed cattle market.

Introduction

Economists are often faced with situations in which a lack of data due to regulatory or other constraints hinders research in an area of interest. One such area is the fed cattle market. Researchers have little access to data on individual fed cattle transactions, and even less with regard to the specific participants in those transactions. As such, it is particularly difficult to discern the extent to which the individual characteristics of firms that buy and sell fed cattle influence the transaction price. The Fed Cattle Market Simulator (FCMS) was developed by a team of researchers at Oklahoma State University (OSU) to model the real fed cattle market and allow the behaviour of different types of feedlot and beef packing firms to be observed. Such an experimental market allows researchers to study topics that are relevant to the real market, but for which real market data are not available.

Since its inception, data from the FCMS has provided the basis for a number of professional presentations and publications (Ward et al.(1996), Ward et al. (1999), Anderson et al.). The FCMS has also been incorporated as a teaching device at a number of universities, and has been used as an extension tool. It simulates the United States fed cattle market by placing participants in the roles of feedlot marketing managers (fed cattle sellers) and packing plant procurement agents (fed cattle buyers). To reflect the real market oligopsony that exists, four packers and eight feedlots trade cattle in the FCMS. These packers and feedlots buy and sell paper pens of cattle during six-to-ten minute trading sessions, during which open negotiations take place. Agents representing the packers are allowed to roam the trading room to visit the locations of various cattle feeders. Each feedlot has a show list of pens of cattle of various weights for sale, and when a transaction is made, the price, weight, type of sale (cash or forward) and number of pens traded is reported to game administrators. This data is then used to update current market information, which is displayed electronically to all participants. All packers and feedlots receive financial statements at the conclusion of each trading period, and can therefrom discern the success of their marketing or procurement strategy. A complete description of the FCMS is given in Ward et al. (1996).

Previous research involving data from the FCMS has not attempted to capture the dynamics of the fed cattle price discovery process. It has failed to account for the fact that fed cattle transaction prices cannot fully adjust on a week-to-week basis because of factors which hold transaction prices close to their previous values. Accordingly, a partial-adjustment model is believed to be appropriate for this problem.

The purpose of the research reported in this paper is to model the dynamic nature of price discovery in the experimental market for fed cattle via a partial-adjustment framework. A mixed linear model, which allows the means and variances of data to be modeled, is used. Since the partial-adjustment model allocates a substantial portion of influence to the lagged dependent variable, other factors previously thought to affect transaction prices may be found to be insignificant. The main contribution of the paper is a better understanding of the dynamic price discovery and price adjustment process for fed cattle.

The Partial-Adjustment Model

Partial-adjustment models are used when it is appropriate to assume that the "desired" rather than the actual value of the dependent variable is determined by the independent variables (Kennedy). Since the desired level of the dependent variable is unknown, this relationship cannot be estimated directly. Accordingly, a simple rule must be specified to describe the manner in which the actual value of the dependent variable adjusts toward the desired value. If the desired value of the dependent variable is:

$$(1) \qquad Y_t^* = \beta_0 + \beta_1 X_t + e_t$$

then (1) asserts that the desired level of the dependent variable is a function of the independent variables and the error term. The adjustment process can be represented by:

$$(2) \qquad Y_t - Y_{t-1} = \gamma(Y_t^* - Y_{t-1}) + u_t$$

which says that the difference between the value of the dependent variable in the current period and its value in the previous period equals the difference between the desired value of the dependent value in the current period and the actual value of the dependent variable observed in the previous period, multiplied by γ, the partial-adjustment factor. By substituting (1) into (2) in order to replace the unobservable Y_t^*, and then performing algebraic manipulation of the variables, the final form of the partial-adjustment model is obtained:

$$(3) \qquad Y_t = \gamma\beta_0 + (1 - \gamma)\, Y_{t-1} + \gamma\beta\, X_t + (\gamma e_t + u_t)$$

This final form of the equation is autoregressive: all values are known and the equation can now be estimated.

The partial-adjustment model is an appropriate framework for examination of the market for fed cattle. Matthey and Royer note that technological rigidities, habit inertia, resource constraints, and institutional control often contribute to slow adjustment processes. Because of the very long biological lag in the beef production system, cow-calf production cannot respond immediately to price changes, resulting in a chronic oversupply or undersupply of beef. As a result, the price of beef can only partially adjust to its long-run equilibrium value in a given period. Since the value of $(1 - \gamma)$ is the parameter estimate for the lagged price in the regression model, large values of the estimate correspond to low adjustment (γ) values from period to period.

The Mixed Linear Model

The mixed linear model provides researchers with the flexibility to model not only the means of their data, but the variances and covariances as well. Since normally distributed data can be completely described by their means and variances, they can have their complete probability distributions specified by the parameters of a mixed linear model.

In the mixed linear model, the fixed-effects parameters describe the mean model, and are associated with known regressors. The variance-covariance model is described by the parameters in the variance equation. The model takes the following general form:

(4) $$Y = \mathbf{X}\beta + \mathbf{Z}\gamma + e$$

where Y is the usual dependent variable, X is the matrix of observations on the regressors, β is the vector of fixed effects parameters, Z is the known design matrix, γ is the vector of random effects parameters, and e is the error term.

Random effects exist in FCMS data because transactions are reported in the form of unbalanced panels. There are between thirty and forty-five transactions in each trading period in the FCMS, and correlation exists between transaction prices within each session. A random effects model considers the extent to which the intercept for each trading period deviates from the overall intercept, and corrects for the heteroskedasticity that would exist in the standard linear model in the absence of such correction.

Data

FCMS data for this study were collected from an undergraduate agricultural economics course that met weekly during the spring semester of 1994. Teams of agricultural economics, animal science, and agricultural education students—primarily juniors and seniors—played the roles of feedlot and packing plant managers during that time. A total of 2154 observations, representing sixty trading sessions with an average of just under thirty-six transactions per session, are used.

Procedures

Ward et al. (1996) outlined the factors that influence price discovery in the FCMS. Table 1 gives the variables and their expected signs. In this study, a lagged dependent variable is added as a regressor to transform the model into one characterized by partial adjustment. The equation estimated in the partial-adjustment, mixed linear model is therefore:

$$(5)\ PR_t = \beta_0 + \beta_1 PR_{t-1} + \beta_2 BBP_{t-1} + \beta_3 FUT_{t-1} + \beta_4 MKT_{t-1} + \beta_5 TSL_{t-1} + \beta_6 PPL_t + \sum_{j=1}^{5} \beta_{7j} DWT_{ij} + \sum_{k=1}^{2} \beta_{8k} DTYPE_{ikt} + \sum_{l=1}^{4} \beta_{9l} DPCKR_{ilt} + \sum_{m=1}^{8} \beta_{10m} DFDR_{imt} + e_{it}$$

where, PR_t is the fed cattle transaction price, PR_{t-1} is the lagged price, and all other variables are as defined in Table 1. Equation (5) is estimated in SAS using the method of restricted maximum likelihood. Specifying the trading session as a random effect allows the hypothesized common correlation among all observations traded in the same period to be introduced.

Results

Table 2 shows the results of estimation of the partial-adjustment, mixed linear model. The coefficient on lagged price is 0.838, which is $(1 - \gamma)$ as described earlier. This means that the price of fed cattle in the FCMS adjusts only approximately sixteen percent (1 – 0.838) toward the long-run desired level on a weekly basis. This is consistent with the assertion that there are long lags in the adjustment process for fed cattle prices. The long-run equilibrium price is constantly being sought within the market, but the price is slow to adjust to the desired level, due in part to the biological constraints that exist in the beef supply chain. Though the structure of the FCMS does not explicitly include the cow-calf herd—and thus a mechanism for altering the biological production within simulations—it does vary the supply of feeder cattle available on a weekly basis. By contracting and expanding the number of available feeder cattle, the FCMS in essence captures the biological production lag.

The coefficient on lagged boxed beef prices is positive, as expected, and significant at the 0.05 level. This is consistent with the results of Ward et al. (1996) who note that this parallels previous research and is consistent with the theory of derived demand. Lagged live cattle futures closing price has the expected positive sign but is not significant, again echoing the results of Ward et al. (1996). They observe that little hedging occurred in the FCMS during the period of study, and that the experiment at that time did not differentiate between hedging and speculating as uses of futures contracts. Additionally, no formal relationship between the futures price and the cash price is built into the FCMS; futures market prices are predicated only upon the expectations of the participants who use futures contracts. As such, the significance of the variable may be affected.

The two supply variables exhibit the expected relationships with transaction prices in the FCMS. Lagged marketings are negative and significant at the 0.10 level, suggesting that a greater number of animals slaughtered decreases prices paid for fed cattle. The coefficient on the total show list variable is also negative and significant, as it is in Ward et al. (1996) and other previous work. The combined implication of these two findings is consistent with theory, which suggests that a relatively greater supply of fed cattle should depress the price received for them.

Potential profit or loss is included as a proxy for the bargaining range between packers and feedlots. The estimated coefficient for potential profit or loss is negative and significant, as expected. This echoes the findings of Ward et al. (1996), as does the finding of a significant negative coefficient for the cash transaction type.

Little importance is attached to the signs or significance of the dummy variables for weight class, or individual packers or feeders. Because of different levels of negotiating and managerial skills among teams, some feeders received lower prices than others for fed cattle; analogously, some packers paid slightly higher prices than did their competitors. Similarly, teams' skills in using cash versus contract marketing varied considerably; the profitability of a team was relatively greater the greater its ability to effectively use the marketing tools at its disposal.

Summary and Conclusions

The goal of this paper was to capture the dynamic aspects of price discovery in an experimental market for fed cattle via the use of a partial-adjustment, mixed linear model. A partial-adjustment model was used because it is well known that due to the long biological production lags that exist in the beef supply chain, the actual price paid for fed cattle can only adjust partially toward the unobservable desired long-run value in any given trading period.

The mixed linear model was employed because it allows the means as well as the variances and covariances of Fed Cattle Market Simulator (FCMS) data to be modeled. For the mean equation, a model similar to that of Ward et al. (1996) was estimated using the method of restricted maximum likelihood. Random effects due to the trading period were introduced into the variance equation. This was done to represent the dual-component error term that characterizes panel data, such as that generated by the FCMS.

Results indicate that the partial adjustment factor for transaction prices in the FCMS was approximately sixteen percent. This was consistent with prior beliefs; specifically, that prices are slow to adjust in the fed cattle market. Other factors thought to be significant in influencing the price of fed cattle—such as lagged boxed beef prices, lagged live cattle futures prices, lagged marketings, lagged total show list, and potential profit or loss—were found to be important. Moreover, findings echoed those consistent with theory and previous research.

Previous research did not take dynamic factors affecting price discovery in the FCMS into account. This study has shown that doing so does not, for the most part, affect factors previously thought to be important in determining transaction prices for fed cattle. What a dynamic analysis such as the one contained herein does contribute is a better understanding of the long run forces that help determine transaction prices in the short term. The partial-adjustment framework, estimated within a mixed linear model, has been shown to be an appropriate method for capturing the long-term effects of factors such as production lags on short-term price discovery. As better real market data becomes available, this type of framework should be used to study actual fed cattle sales. In this way, an enhanced understanding of the functioning of the fed cattle market will be gained.

Table 1. Transaction Price Determinants in Fed Cattle Market Simulator (FCMS)

Variable	Definition	Expected Sign
BBP_{t-1}	boxed beef price ($/cwt) for Choice YG 1-3 550-700 lb carcasses, lagged one period	+
FUT_{t-1}	live cattle futures closing price for the nearby futures month, lagged one period	+
MKT_{t-1}	total pens of cattle marketed/purchased, lagged one period	-
TSL_{t-1}	total pens of cattle on the show list at the end of (t-1)	-
PPL_{t}	potential profit or loss in period t, based on packer break-even price less feedlot breakeven price for 1,150 lb cattle	-
DWT_{ijt}	zero-one dummy variable for weight class; j=1-5, 1=1,100 lbs, 2=1,125 lbs, 3=1,150 lbs, 4=1,175 lbs 5=l,200 lbs, Base=1,150 lbs	+/-
$DTYPE_{ikt}$	zero-one dummy variable for transaction type; k=1-2 1=cash 2=forward contract Base=forward contract	+/-
$DPCKR_{ilt}$	zero-one dummy variable for individual packers; l=1-4 1=PCKR1 2=PCKR2 3=PCKR3 4=PCKR4 Base=PCKR1	+/-
$DFDR_{imt}$	zero-one dummy variable for individual feedlots; m=1-8 1=FDR1 2=FDR2 3=FDR3 4=FDR4 5=FDR5 6=FDR6 7=FDR7 8=FDR8 Base=FDR1	+/-

Table 2. Parameter Estimates for Partial-Adjustment, Mixed Linear Model

Variable	Parameter Estimate	Standard Error
Intercept	3.039*	0.617
Lagged Price	0.838*	0.011
Lagged Boxed Beef Price	0.084*	0.006
Lagged Live Cattle Futures Closing Price	0.004	0.007
Lagged Total Marketings	-0.004**	0.002
Lagged Total Show List	-0.004*	0.001
Potential Profit or Loss	-0.085*	0.008
Weight Class #1	0.031	0.181
Weight Class #2	-0.009	0.039
Weight Class #4	-0.087*	0.035
Weight Class #5	-0.166*	0.048
Cash Transaction	-0.095**	0.052
Packer #2	-0.204*	0.042
Packer #3	-0.112*	0.039
Packer #4	-0.014	0.039
Feedlot #2	-0.018	0.053
Feedlot #3	-0.060	0.053
Feedlot #4	0.002	0.053
Feedlot #5	-0.155*	0.053
Feedlot #6	0.005	0.050
Feedlot #7	-0.040	0.053
Feedlot #8	0.002	0.054

Notes: single and double asterisks denote significance at the 0.05 and 0.10 levels

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