Factors Influencing Marketing Margins in Cattle and Beef Markets

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Introduction

Cattle and beef prices in the first quarter of 2010 have been, for the most part, an improvement from the prices experienced in much of 2009. First quarter Choice boxed beef values were approximately 5% above the first quarter in 2009. The five-area weighted average price for live steers was about 8% higher in the first quarter of 2010 compared to the first quarter of 2009. The price of 750 to 800 pound steers at Oklahoma City auction markets improved just over 7% in the same time frame. Despite the improvement, stocker operators and feeders are likely less enthusiastic about the high prices due to the environment in which they operate. Given the inherent nature of commodity markets these operators function on typically thin margins. More specifically, in times of high prices these operators purchase expensive cattle and must rely on the market to maintain its strength to remain at or above break-even when selling. Furthermore, the high prices increase the capital requirements of these operators.

Beef processors, feedlots, and stocker grazing/backgrounding enterprises all operate on a margin. Their gross margin is determined by the difference between the cost of the animals entering their production system and the value of the product sold at the end of the production system. This situation is common to any firm involved in adding form utility to a raw or intermediate product. In the beef industry, though, the estimation of these marketing margins is complicated by the long production lags. The long lags are primarily found in the backgrounding and feeding phases of the production system. For these operations in particular, the marketing margin is influenced not only by the differences in form between input and output but by the dynamic behavior of prices over the course of a three or four month long production cycle. To a lesser extent, beef processors also rely on market stability when making purchasing decisions since pens of cattle are often bought anywhere from seven to 21 days in advance.

Of course, the cost of adding weight also factors into the equation for stockers and feeders and so the relative price of feed, hay and forage is important as well. As such, another aspect to consider regarding the marketing margin that stockers and feeders operate under is the relationship between prices of cattle in different weight classes. This relationship is well-known in the industry and is popularly referred to as the price/weight slide (or, more simply, the price slide). Generally, the price slide reflects an inverse relationship between cattle weight and price per pound. This relationship arises from the fact that it is generally possible to put weight on an animal for less than the value of that additional weight. Thus, lighter cattle are worth more per unit than heavier cattle because the potential profit from adding weight to the lighter animals is bid into their price. Analyses of the price slide are relatively common in the agricultural economics literature. Dhuyvetter, Schroeder, and Prevatt (2001) quantify the impact of key related prices (corn and fed cattle) on feeder cattle price slides. Brorsen et al. (2001) analyze formal price slides used in feeder cattle pricing arrangements, finding that such slides are generally not sufficient to ensure accurate estimates of feeder cattle sale weights by sellers.

While work on feeder cattle price slides is useful in the context of feeder cattle marketing and price discovery, it sheds very little light on the issue of marketing margins in the backgrounding and feeding phases of beef production. Price slides reflect differences in contemporaneous prices and do not take into account the very significant production lags inherent in the beef industry. Other authors have directly addressed the behavior of marketing margins but have generally not attempted to fully incorporate an accurate representation of the dynamic character of production. Research exploring marketing margins in the beef sector has largely been spurred by meat packer concentration concerns (Azzam and Anderson). The bulk of this literature focuses on the margin between feeders and processors and/or processors and retailers. Holt (1993) develops a three equation structural model of farm-retail beef price spreads. This work does not, however, extend farm level analysis any further upstream than the fed cattle level, thus avoiding the longer production lags in the backgrounding and feeding sectors. Similarly, Goodwin and Holt (1999), in evaluating price transmission in the beef industry define farm-level prices at the fed cattle level.

A recent study by Marsh and Brester states that from 1970 to 1998 the margin between beef wholesalers (processors) and retailers increased by 27%. Their model based on inverse demand and supply equations indicate that a multitude of factors impact wholesale-to-retail beef margins; however, again this analysis does not go any further back in the production system than the processor level. The United States Department of Agriculture (USDA) annually reports a farm-to-retail statistic; however, Brester, Marsh and Atwood (2009) determine that this margin is not a reliable indicator.

In summary, existing research examines contemporaneous price relationships in the feeder cattle market as well as marketing margins between the fed cattle and retail beef markets. Very little work has been done however, on intertemporal price relationships upstream from the fed cattle market. Price relationships across time and across stocker/feeder cattle classes represent marketing margins for backgrounding and feeding operations.

Research Objectives

The general objective of this research is to define the factors that influence marketing margins in the beef industry. Specific objectives are twofold. First, this work will develop a conceptual model of marketing margins for backgrounding operations, feeding operations, and beef processors that explicitly incorporates realistic production lags at the backgrounding and feeding stages. Second, an empirical model will be estimated that quantifies the impact of key variables on beef industry marketing margins.

Conceptual Framework

Following Gardner (1975) and Holt (1993), we assume that backgrounders and feeders operate in competitive markets. In addition, similar to Holt, we assume that both backgrounders and feeders form rational expectations of output price and price risk.

We assume, as in Brorsen et al. (1985), that a price-taking firm (a backgrounder or feeder) produces output y from a raw input x and a vector $\mathbf{z}$ of other inputs according to production function

(1) $y = f(x,\mathbf{z})$.

We further assume that the production function is weakly separable and that y is produced in fixed proportions from the raw input x while other inputs $\mathbf{z}$ are used in variable proportions. Thus, each firm's technology can be represented by the Leontief production function

(2) $y = min[x/k, g(\mathbf{z})]$

where k is a positive constant. Let p denote the output price, r the price of the input x and $\mathbf{q}$ the vector of prices for other inputs $\mathbf{z}$. The cost function associated with (2) is

(3) $C(r,\mathbf{q},y) = min_{x,\mathbf{z}}[rx+\mathbf{q}'\mathbf{z}] = rx^*(r,y)+\mathbf{q}'\mathbf{z}^*(\mathbf{q},y) = rky+\mathbf{q}'\mathbf{z}^*(\mathbf{q},y)$

where $x^*(r,y) = ky$ and $\mathbf{z}^*(\boldsymbol{q},y)$ are the cost-minimizing input demand functions, and C is a linear homogeneous function, increasing and concave in prices (r, $\boldsymbol{q}$) and increasing and strictly convex in output y.

The firm profit function is then

(4) $\pi = (p - kr)y - \widetilde{C}(\boldsymbol{q},y)$

where $\widetilde{C}(\boldsymbol{q},y) = \boldsymbol{q}'\mathbf{z}^*(\boldsymbol{q},y)$ is the cost for the variable inputs $\mathbf{z}$.

The random (inverse) demand schedule faced by the firms is given by

(5) $p = \widetilde{p}(Y,\mathbf{s}) + \sigma\varepsilon$

where $Y = my$ is industry output, m is the number of firms, $\boldsymbol{s}$ is a vector of exogenous demand shifters and ε is a random variable with $E(\varepsilon) = 0$ and $E(\varepsilon^2) = 1$. The expected output price is then $E(p) = \widetilde{p}(Y,\mathbf{s})$ and the variance of the output price is σ^2.

Under the assumption that backgrounders and feeders goal is to maximize the expected utility of the firm's wealth, then they make the production decisions based on

(6) $Max_y \, EU[w_0 + (p - kr)y - \widetilde{C}(\boldsymbol{q},y)]$

where w_0 is the initial wealth, $U(w)$ is an increasing ($\partial U/\partial w > 0$) and concave ($\partial^2 U/\partial w^2 < 0$) function for a risk-averse firm, and E is the expectation operator. Taking the first-order condition of (6) we obtain

(7) $E[U'\{(p - kr) - \widetilde{c}(\boldsymbol{q},y)\}] = \widetilde{p}(Y,\mathbf{s}) - kw - \widetilde{c}(\boldsymbol{q},y) + cov(U',p)/EU' = 0$

where $\widetilde{c}(\boldsymbol{q},y) = \partial\widetilde{C}(\boldsymbol{q},y) = \boldsymbol{q}'\mathbf{z}^*(\boldsymbol{q},y)$ and $cov(U',p)/EU' = \rho\{\gamma^2 \cdot E[U' - EU']^2\}^{1/2}$ is the covariance between U' and p, with ρ being the correlation between marginal utility and output price. Under risk version, output price and marginal utility are negatively correlated (Baron, 1970). The solution to (7) is the firm's supply function. Given our focus on the marketing margin, one can obtain the function for the expected marketing margin (Brorsen et al., Holt) by inverting the firm's supply function

(8) $\tilde{p}(Y,\boldsymbol{s}) - kw = \tilde{c}(\boldsymbol{q}, y) + \delta^{*}\gamma$

where $\delta^{*} = -(\mathrm{E}U')^{-1}\rho\{\mathrm{E}[U' - \mathrm{E}U']^{2}\}^{1/2}$. Given that ρ is negative, δ^{*} will be positive.

Assuming that the industry behaves like a representative firm, the aggregate expected margin equation for the backgrounding and feeding operations is

(9) $\tilde{M} = \tilde{p}(Y,\boldsymbol{s}) - kw = \Pi(\boldsymbol{q}, Y) + \delta_{1}\gamma + e$

where $\tilde{M}$ denotes expected margin and e is a stochastic error term. Brorsen et al. show that under decreasing absolute risk aversion (DARA) $\partial\tilde{M}/\partial Y > 0$, $\partial\tilde{M}/\partial q_i \geq 0$ $(\leq=0)$ as $\partial Y/\partial q_i \leq 0$ $(\geq=0)$, and $\partial\tilde{M}/\partial\gamma > 0$.

Data and Empirical Procedures

The empirical model consists of six equations, three for the backgrounding operations and three for the feeding operations. For each of the two operations, the first and second equations represent respectively the demand for and the supply of cattle/beef at that operation. The third equation represents the marketing margin for the operation. Expected prices for feeder cattle are obtained from price of the futures contract for feeder cattle with a maturity date four months from the current date. Similarly, the expected price risk for feeder cattle is obtained from the implied volatility for the same feeder cattle contract. The marketing margin for the backgrounding operation is then defined as the difference between the expected price for feeder cattle and the current price for steers in the 500-600 pounds category. Expected prices for fed cattle are obtained from the price of the futures contract for live cattle with a maturity date five months from the current date. In addition, the expected price risk for fed cattle is obtained from the implied volatility for the same fed cattle contract. The marketing margin for the feeding operation is defined as the difference between the expected price for fed cattle and the current price for steers in the 700-800 pounds category. Appropriate weight conversions are also taken into account when calculating both margins. Specifically, an average weight of 500, 750, and 1,200 pounds is used respectively for stocker, feeder and fed cattle. Figure 1 displays the marketing margins for the feeding and backgrounding operations.

Data are monthly observations from January 1990 to September 2009. Cash prices for feeder cattle are from the *Weekly Weighted Average Summary* of cash prices reported by USDA's Agricultural Marketing Service (AMS) for Oklahoma City. Feeder cattle quantity is from the National Agricultural Statistics Service's (NASS) monthly *Cattle on Feed* report[1]. Cash fed cattle prices are from AMS's *Five Area Daily Weighted Average Direct Slaughter Cattle* report and wholesale beef prices are from AMS's *National Weekly Boxed Beef Cutout and Boxed Beef Cuts* report. The Chicago cash price for corn from AMS's *Weekly Feedstuff Wholesale Prices* report are used. Futures prices and implied volatilities for feeder and fed cattle are obtained from the *Commodity Research Bureau*. The consumer price index (CPI) (1982 = 100), and the wage rate for the feeding operations are obtained from the *Bureau of Labor Statistics*. The farm wage rate and the energy index are obtained from NASS. All prices are deflated by CPI.

The fed cattle demand is specified as

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[1] For this analysis the feeder cattle supply is the total number of cattle on feed less than 90 days. This is calculated by subtracting the cattle placed on feed greater than three months out from the current cattle on feed total.

$$\begin{aligned}(10)\quad &\Delta P_t^1 = \alpha_0 + \alpha_1 \Delta P_t^{BB} + \alpha_2 \Delta P_{t-1}^{BB} + \alpha_3 \Delta P_{t-2}^{BB} + \alpha_4 \Delta P_{t-3}^{BB} + \alpha_5 \Delta Q_t^1 + \alpha_6 \Delta Q_{t-2}^1 + \alpha_7 \Delta Q_{t-3}^1 \\ &+ \alpha_8 ZP_{t-1}^1 + \alpha_9 SIN1 + \alpha_{10} COS1 + \alpha_{11} SIN2 + \alpha_{12} COS2 + \sum_{i=1}^{11} \alpha_{12+i} \Delta P_{t-i}^1 + \varepsilon_{1t}\end{aligned}$$

where Δ is the first-difference operator, P^1 is the five-area weighted average live weight price for fed steers in cents per pound, Q^1 is commercial beef production in million pounds, P^{BB} following Marsh (2007) is the cut-out (wholesale) value of beef, *SIN*1, *SIN*2, *COS*1, and *COS*2 are harmonic variables used to capture the six- and twelve-month cycles[2], and $\alpha_0, \ldots, \alpha_{23}$ are parameters. Current and lagged values of the commercial beef production and the wholesale value of beef are included to capture the gradual response to quantity and wholesale price changes. Similarly, the lagged values of price changes capture short-run dynamics of fed cattle prices. Finally, ZP^1 is an error correction term capturing the cointegrating relation between the P^1 and P^{BB}. We test, using Dickey-Fuller (19179, 1981) and Phillips-Perron (1988) tests, whether P^1 and P^{BB} are stationary. Both tests indicate that P^1 and P^{BB} are I(1). Next, we use Johansen (1992) procedure to determine whether a linear combination (cointegrating vector) that is I(0) exists between P^1 and P^{BB}. Results of cointegration testing and parameter estimates of the cointegrating vector used to construct ZP^1 are reported in table 1.

The fed cattle supply is specified as

$$\begin{aligned}(11)\quad &Q_t^1 = \beta_0 + \beta_1 P_t^2 + \beta_2 P_t^C + \beta_3 \sigma_t^1 + \beta_4 SIN1 + \beta_5 COS1 + \beta_6 SIN2 + \beta_7 COS2 \\ &+ \sum_{i=1}^{11} \beta_{7+i} Q_{t-i}^1 + \varepsilon_{2t}\end{aligned}$$

where P^2 is the five-area weighted average live weight price for feeder steers in cents per pound, P^C is the price of corn, and σ_t^1 is the implied volatility for fed cattle price.

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[2] The harmonic variables are $SIN1 = sin(2\pi t/6)$, $COS1 = cos(2\pi t/6)$, $SIN2 = sin(2\pi t/12)$, and $COS2 = cos(2\pi t/12)$, $t = 1, \ldots, T$.

The equation for the expected margin for the feeding operations is specified as

$$(12)\quad \begin{aligned} \Delta\widetilde{M}_t^1 &= \gamma_0 + \gamma_1\Delta Q_t^1 + \gamma_2\Delta P_t^C + \gamma_3\Delta WR_t^P + \gamma_3\Delta PE_t + \gamma_4\sigma_t^1 + \gamma_5 Z\widetilde{M}_t^1 + \gamma_6 SIN1 + \gamma_7 COS1 \\ &+ \gamma_8 SIN2 + \gamma_9 COS2 + \sum_{i=1}^{11}\gamma_{9+i}\Delta\widetilde{M}_{t-i}^1 + \varepsilon_{3t} \end{aligned}$$

where $\Delta\widetilde{M}_t^1 = w_1 \mathrm{E}[P_{t+5}^1] - w_2 P_t^2$ and $\mathrm{E}[P_{t+5}^1]$ is the price of the futures contract for live cattle with a maturity date five months from the current date, w_1 and w_2 are respectively the average weights for fed and feeder cattle, WR^P is the wage rate for the feeding industry, PE is an energy index, and $Z\widetilde{M}^1$ is an error correction term capturing the cointegrating relation between the $\widetilde{M}^1$, P^C, WR^P, and PE, based on the testing procedure for unit root and cointegration as mentioned above.

The feeder cattle demand and supply, and the expected margin for the feeding operations are, respectively, specified as

$$(13)\quad \begin{aligned} \Delta P_t^2 &= \varphi_0 + \varphi_1\Delta P_t^1 + \varphi_2\Delta P_{t-1}^1 + \varphi_3\Delta P_{t-2}^1 + \varphi_4\Delta P_{t-3}^1 + \varphi_5\Delta Q_t^2 + \varphi_6\Delta Q_{t-2}^2 + \varphi_7\Delta Q_{t-3}^2 \\ &+ \varphi_8 ZP_{t-1}^2 + \varphi_9 SIN1 + \varphi_{10} COS1 + \varphi_{11} SIN2 + \varphi_{12} COS2 + \sum_{i=1}^{11}\varphi_{12+i}\Delta P_{t-i}^2 + \varepsilon_{4t} \end{aligned}$$

$$(14)\quad \begin{aligned} Q_t^2 &= \theta_0 + \theta_1 P_t^3 + \theta_2 P_t^C + \theta_3\sigma_t^2 + \theta_4 SIN1 + \theta_5 COS1 + \theta_6 SIN2 + \theta_7 COS2 \\ &+ \sum_{i=1}^{11}\theta_{7+i} Q_{t-i}^2 + \varepsilon_{5t} \end{aligned}$$

$$(15)\quad \begin{aligned} \Delta\widetilde{M}_t^2 &= \lambda_0 + \lambda_1\Delta Q_t^2 + \lambda_2\Delta P_t^C + \lambda_3\Delta WR_t^F + \lambda_3\sigma_t^2 + \lambda_4 Z\widetilde{M}_t^2 + \lambda_5 SIN1 + \lambda_6 COS1 \\ &+ \lambda_7 SIN2 + \lambda_8 COS2 + \sum_{i=1}^{11}\lambda_{8+i}\Delta\widetilde{M}_{t-i}^2 + \varepsilon_{6t} \end{aligned}$$

where P^3 is the five-area weighted average live weight price for stocker steers in cents per pound, Q^2 is quantity of feeder cattle in million heads, and ZP^2 is an error correction term capturing the cointegrating relation between the P^2 and P^1, σ_t^2 is the implied volatility for feeder cattle price, $\Delta\widetilde{M}_t^2 = w_3\mathrm{E}[P_{t+4}^2] - w_4 P_t^3$ and $\mathrm{E}[P_{t+4}^2]$ is the price of the futures contract for feeder cattle with a maturity date four months from the current date, w_3 and w_4 are respectively the average weights for feeder and stocker cattle, WR^{F} is the wage rate for the backgrounding industry, and $Z\widetilde{M}^2$ is an error correction term capturing the cointegrating relation between the $\widetilde{M}^2$, P^{C}, and WR^{F}.

Based on preliminary analysis GARCH(1,1) processes were adequate for specifying the conditional variance dynamics for the different equations. The conditional variances were specified as

$$(16)\quad \begin{aligned} h_{iit} &= \kappa_{i0} + \eta_{i1}\varepsilon_{it-1}^2 + \psi_{i1}h_{it-1}, \\ h_{ijt} &= \rho_{ij}(h_{iit}h_{jjt})^{1/2}, \end{aligned}$$

$i, j = 1$ (P^1), 2 (Q^1), 3 ($\widetilde{M}^1$), 4 (P^2), 5 (Q^2), 6 ($\widetilde{M}^2$), $i \neq j$.

Results

Results of cointegration testing and parameter estimates of the cointegrating vectors for four equations, two demand and two margin equations, are reported in table 1. Table one reports the Johansen's trace tests for up to two cointegrating vectors. We find at most one cointegrating vector exist for each of the four cases. Table 1 also reports the normalized cointegrating vectors between the respective variables for each equation. The variables are P^1 and P^{BB} for the fed cattle demand equation, $\widetilde{M}^1$, P^{C}, WR^{P} for the feeding margin equation, P^1 and P^2 for the feeder cattle demand equation, and $\widetilde{M}^2$, P^{C}, and WR^{F} for the backgrounding margin equation.

Results shown in table 2 relate to the fed cattle equations and these retuned the expected signs for the demand and supply equations. Specifically, an increase in the wholesale price of beef (the boxed beef cutout value) results in an increase in demand for fed cattle. As beef production increases fed cattle price declines. Beef production is negatively influenced by the price of feeder cattle inputs. An increase in corn price has a positive impact on beef production while an increase in fed cattle price risk has a negative impact on beef production. However, both these effects, in our model, are not significant at conventional levels.

Referring to the elasticities in table 4, we find from the fed cattle demand equation that a one percent increase in the price of boxed beef and the total pounds of beef produced results in a 0.859 percent increase and a 0.063 percent decrease in the five area fed cattle price, respectively. For the supply equation for fed cattle, beef production declines by 0.044, 0.01 and 0.024 percent with respect to a one percent increase in the price of feeder cattle, the price of corn and the implied volatility of live cattle futures prices, respectively.

Elasticities calculated from the feeding margin equation indicate that increases in corn price, wages and energy prices all cause the feeding margin to widen. Wages have the largest impact on the feeding margin. A one percent increase in wage rates result in a 0.844 percent increase in the feeding margin. With a one percent increase in the price of corn the feeding margin increases by 0.309 percent. A one percent increase in the energy price index increases the feeding margin by 0.494 percent. A one percent increase in current beef production leads to a 0.127 decrease in the feeding margin while a one percent increase in the volatility of futures prices result in a 0.016 percent increase in the feeding margin.

Table 3 provides the results for the backgrounding operations. Again, all the estimated coefficients have the expected signs. In regard to the elasticities for the feeder cattle demand and supply equations we find that feeder cattle prices are most influenced by the cash price of fed cattle. A one percent increase in the five area cash price of fed cattle result in a 0.437 percent increase in feeder cattle prices. Feeder cattle supply is negatively impacted by the price of 500 pound incoming calves, corn price and increased feeder cattle price risk.

For the backgrounding margin equation, again, wages have the largest impact. A one percent increase in the wage rate results in a 1.334 percent increase in the backgrounding margin. With a corn price and quantity of feeder cattle supplies increase of one percent the backgrounding margin increases by 0.237 and 0.127 percent, respectively. The margin decreases by 0.054 percent as the implied volatility, a measure of price risk, increases by one percent.

Conclusions

Previous beef marketing margin research has focused on the wholesale to retail level. This analysis moves further upstream in the beef production system to determine the factors that impact the feeder calf to fed cattle and the fed cattle to wholesale marketing margins. We employ a six equation model that incorporates fed and feeder cattle supply and demand equations and the margins for each of these two industry segments.

The marketing margin equations are the focal point of this analysis. For the feeding and backgrounding margin wage rates have the largest overall impact. Corn prices, which have risen sharply since 2007, have a positive influence on both margins. Increasing corn prices cause the feeding margin to increase faster than the backgrounding margin while higher wages have a greater impact on backgrounding margin as opposed to feeding margin. The level of price risk, represented by the implied volatility of feeder and live cattle futures prices, have opposing impacts on each margin. Increasing fed cattle price risk causes the feeding margin to increase while increasing feeder cattle price risk reduces the backgrounding margin. The first part of this is in line with Holt (1993). He explains that positive influence from price risk stems from the fact that fed cattle are also viewed as an investment. Backgrounders on the other hand are more likely to view their operation in a business framework.

Table 1. Cointegration Test Results and Cointegrating Vectors

	Johansen Cointegration Test[a]				Normalized Cointegrating Vector[b]					
Equation	Test	$r = 0$	$r = 1$	$r = 2$						
Fed Cattle	Trace	55.38	12.35		Variables	Constant	P^1	P^{BB}		
Demand		(29.38)	(15.34)			-	1.0	0.66		
								(<0.001)		
Feeding Margin	Trace	68.27	26.84	11.66	Variables	Constant	$\tilde{M}^1$	P^C	WR^P	PE
		(53.42)	(34.80)	(19.99)		253.4	1.0	50.76	-163.08	0.66
								(<0.001)	(0.030)	(0.001)
Feeder Cattle	Trace	24.48	6.65	-	Variables	Constant	P^1	P^2		
Demand		(19.99)	(9.13)	-		-	1.0	0.63		
								(0.007)		
Backgrounding	Trace	95.48	15.45	4.37	Variables	Constant	$\tilde{M}^2$	P^C	WR^F	
Margin		(34.80)	(19.99)	(9.13)		-135.93	1.0	20.57	1.15	
								(<0.001)		

Note: [a] Numbers in parentheses are 5-percent critical values.
[b] Numbers in parentheses are p-values.

Table 2. Maximum Likelihood Estimates of a Multivariate GARCH Model of the Beef Feeding Operations

Equation	Parameter	Variable	Coefficient	Standard Error
Fed Cattle Demand	α_0	Constant	0.020	0.004
	α_1	$\Delta P^{BB}t$	0.451	0.020
	α_2	$\Delta P^{BB}t\text{-}1$	0.076	0.037
	α_3	$\Delta Q^{I}t$	-0.261	0.084
	α_4	$ZP^{I}t$	-0.209	0.045
	α_5	$SIN1$	0.004	0.002
	α_6	$SIN2$	-0.003	0.002
	α_7	$COS1$	-0.011	0.002
	α_8	$COS2$	0.006	0.002
	$\alpha_{9\text{-}19}$	$\Sigma\Delta P^{I}t\text{-}i$	-0.123	
Fed Cattle Variance	κ_{10}	Constant	0.099	0.070
	η_{11}	$\varepsilon_{1t\text{-}1}$	0.056	0.055
	ψ_{11}	$h_{1t\text{-}1}$	0.675	0.212
Fed Cattle Supply	β_0	Constant	8.403	2.064
	β_1	$P^{2}t$	-0.929	0.511
	β_2	$P^{C}t$	-0.067	0.065
	β_3	σ^{I}_{t}	-0.041	0.028
	β_4	$SIN2$	-0.697	0.188
	β_5	$COS1$	0.232	0.099
	β_6	$COS2$	-1.072	0.221
	$\beta_{7\text{-}17}$	$\Sigma Q^{I}t\text{-}i$	0.748	
Feeding Margin	γ_0	Constant	1.705	2.962
	γ_1	$\Delta P^{C}t$	25.383	5.096
	γ_2	$\Delta WR^{P}t$	1.638	1.050
	γ_3	ΔPE_t	1.608	0.630
	γ_4	$\Delta Q^{I}t$	-1.523	0.750
	γ_5	σ^{I}_{t}	2.491	1.624
	γ_6	$Z\widetilde{M}^{1}_{t}$	-0.278	0.053
	γ_7	$SIN1$	-5.136	1.671
	γ_8	$SIN2$	-8.560	1.724
	$\gamma_{9\text{-}19}$	$\Sigma\Delta\widetilde{M}^{1}_{t-i}$	-0.424	
Feeding Margin Variance	κ_{20}	Constant	0.034	0.029
	η_{21}	$\varepsilon_{1t\text{-}1}$	0.112	0.037
	ψ_{21}	$h_{1t\text{-}1}$	0.908	0.030
Log Likelihood			-1706	

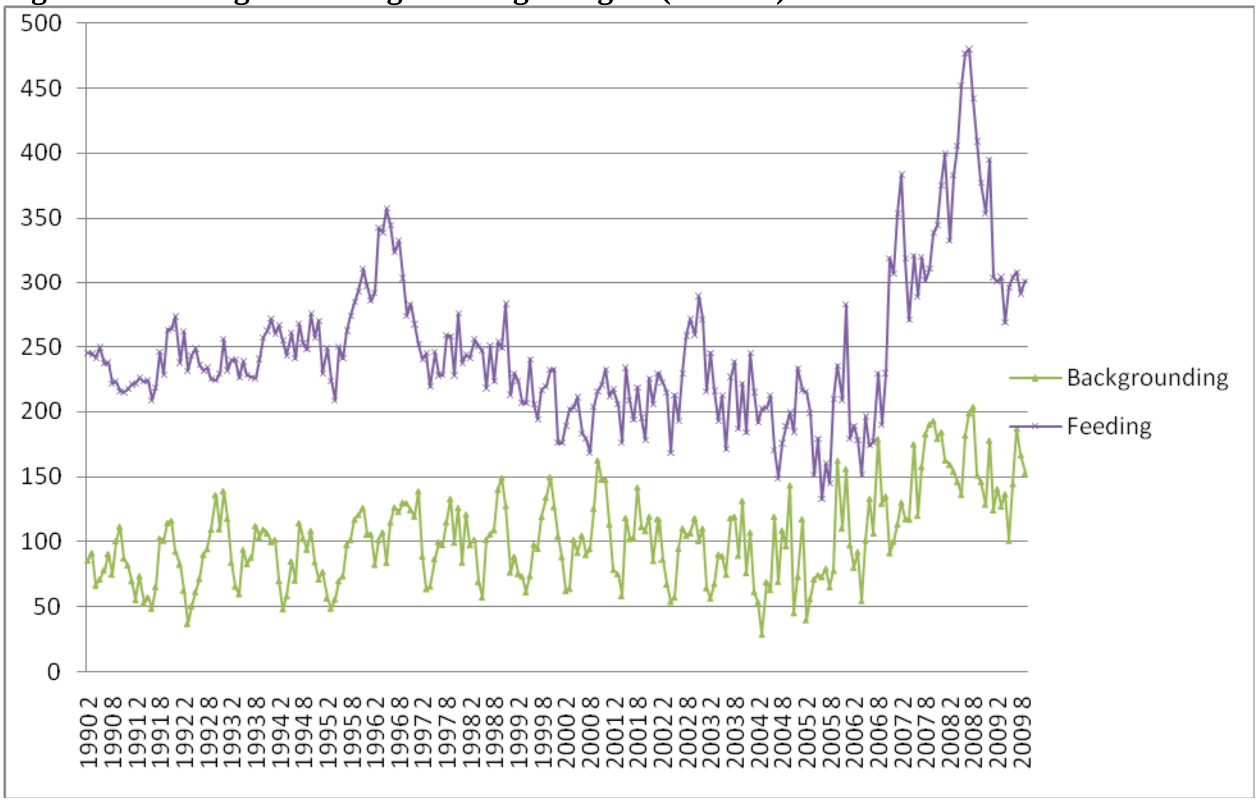
Table 3. Maximum Likelihood Estimates of a Multivariate GARCH Model of the Beef Backgrounding Operations

Equation	Parameter	Variable	Coefficient	Standard Error
Feeder Cattle Demand	φ_0	Constant	-0.014	0.017
	φ_1	$\Delta P^1 t$	0.647	0.047
	φ_2	$\Delta P^1 t$-2	-0.140	0.051
	φ_3	$\Delta Q^2 t$	-0.026	0.012
	φ_4	$\Delta Q^2 t$-1	-0.010	0.005
	φ_5	$ZP^1 t$	0.059	0.026
	φ_6	$COS1$	0.012	0.003
	φ_7	$COS2$	-0.023	0.003
	$\varphi_{8\text{-}18}$	$\Sigma\Delta P^2 t\text{-}i$	0.344	
Feeder Cattle Variance	κ_{30}	Constant	0.004	0.002
	η_{31}	$\varepsilon_{1t\text{-}1}$	0.415	0.169
	ψ_{31}	$h_{1t\text{-}1}$	0.195	0.260
Feeder Cattle Supply	θ_0	Constant	5.497	1.152
	θ_1	$P^3 t$	-0.894	0.680
	θ_2	$P^C t$	-0.136	0.093
	θ_3	σ^2_t	-0.051	0.020
	θ_4	$SIN1$	-1.370	0.238
	θ_5	$SIN2$	-1.402	0.267
	θ_6	$COS2$	-1.572	0.272
	$\theta_{7\text{-}17}$	$\Sigma Q^2_{t\text{-}i}$	0.966	
Backgrounding Margin	λ_0	Constant	6.448	2.785
	λ_1	$\Delta P^C t$	8.110	3.943
	λ_2	$\Delta WR^F t$	0.899	0.492
	λ_3	$\Delta Q^2 t$	0.071	0.033
	λ_4	σ^2_t	-3.637	1.686
	λ_5	$Z\widetilde{M}^2_t$	-0.240	0.073
	λ_6	$SIN2$	-2.615	0.269
	$\lambda_{7\text{-}17}$	$\sum\Delta\widetilde{M}^2_{t-i}$	-1.659	
Backgrounding Margin Variance	κ_{40}	Constant	7.381	3.754
	η_{41}	$\varepsilon_{1t\text{-}1}$	0.045	0.027
	ψ_{41}	$h_{1t\text{-}1}$	0.941	0.033
Log Likelihood			-1706	

Table 4. Estimates of Short-Run Elasticities

Equation	Variable	Elasticity
Fed Cattle Demand	$P^{BB}t$	0.859
	$Q^{1}t$	-0.063
Fed Cattle Supply	$P^{2}t$	-0.044
	$P^{C}t$	-0.010
	σ^{1}_{t}	-0.024
Feeding Margin	$P^{C}t$	0.309
	$WR^{P}t$	0.844
	PE_{t}	0.494
	$Q^{1}t$	-0.127
	σ^{1}_{t}	0.016
Feeder Cattle Demand	$P^{1}t$	0.437
	$Q^{2}t$	-0.073
Feeder Cattle Supply	$P^{3}t$	-0.017
	$P^{C}t$	-0.008
	σ^{2}_{t}	-0.012
Backgrounding Margin	$P^{C}t$	0.237
	$WR^{F}t$	1.334
	$Q^{2}t$	0.127
	σ^{2}_{t}	-0.054

Figure 1. Feeding and Backgrounding Margins (cents/lb)



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