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The Dynamics of Feeder Cattle Market Responses to Corn Price Change

John D. Anderson and James N. Trapp

ABSTRACT

A feeder-calf price model is estimated which incorporates elements of break-even budget analysis, including estimates of placement weights, slaughter weights, ration cost, and feed-conversion rates. From this model, a corn price multiplier is calculated which quantifies the corn/feeder-calf price relationship. Because the multiplier includes information on cattle weight, feed conversion, and ration cost, it also provides insight into how feeding programs are altered in response to corn price changes. Changes in feeding programs which occur in response to corn price changes are illustrated with dynamic simulation based on weight, ration cost, and price models presented here.

Key Words: *corn, corn price multiplier, dynamic simulation, feeder cattle.*

The use of break-even budgeting analysis has frequently been extended by agricultural economists and others to describe and forecast feeder cattle market reactions to various exogenous shocks. This method of forecasting has appeal for use with producers since they readily understand its logic. However, there would appear to be inherent potential dangers in using what is essentially a comparative static micro-level tool as a macro/market-level analysis tool. One potential danger or weakness is that break-even budget analysis appears to ignore the dynamics of the cattle industry. A second danger is that break-even analysis assumes perfectly competitive market responses to all exogenous shocks.

Review of Break-even Analysis Methods and Results

The popular press and professional articles often focus particular attention on the impact of corn price on feeder-calf prices. Given the importance of corn in the feeding process, that focus is warranted. Generally, in commercial feedlots well over two-thirds of the cost of feed can be attributed to grain costs (USDA). The vast majority of this grain is corn. Corn accounts for over 80 percent of all feed grains consumed by U. S. livestock (Ash). Albright, Schroeder, and Langemeier examined cost of gain in two Kansas feedlots and determined that over 60 percent of the variability in cost of gain could be attributed to corn price variability. More recently, Langemeier, Schroeder, and Mintert found that changes in corn price account for 22 percent of the variability in the profits to cattle feeding. Clearly, there is great incentive to investigate the relationship between corn and feeder-calf prices.

Various rules of thumb which attempt to describe the relationship between corn and feeder-calf prices can be found in the popular press. In discussing the corn price/feeder-calf price relationship, the popular press typically uses the term *corn price multiplier* which is defined as the ratio of the long-term change in

The authors are, respectively, assistant extension professor, Department of Agricultural Economics, University of Kentucky and department head, Department of Agricultural Economics, Oklahoma State University.

Table 1. Break-even Feeder-Calf Price Estimate

Fed Cattle Value:	1,200 lbs × \$0.74/lb = \$888
Cost of Gain:	= \$140.63
Pounds of Gain = 1,200 lbs − 750 lbs = 450 lbs	
Bushels of Grain = (450 lbs × 7 lbs grain/lb gain)/56 lbs/bu = 56.25 bu	
Cost of Gain = 56.25 bu × \$2.50/bu = \$140.63	
Net Revenue:	\$888 − \$140.63 = \$747.37/head
Break-even Feeder Price:	\$747.37 ÷ 750 lbs = \$0.9965/lb

Note: A bushel of corn is assumed to weigh 56 lbs.

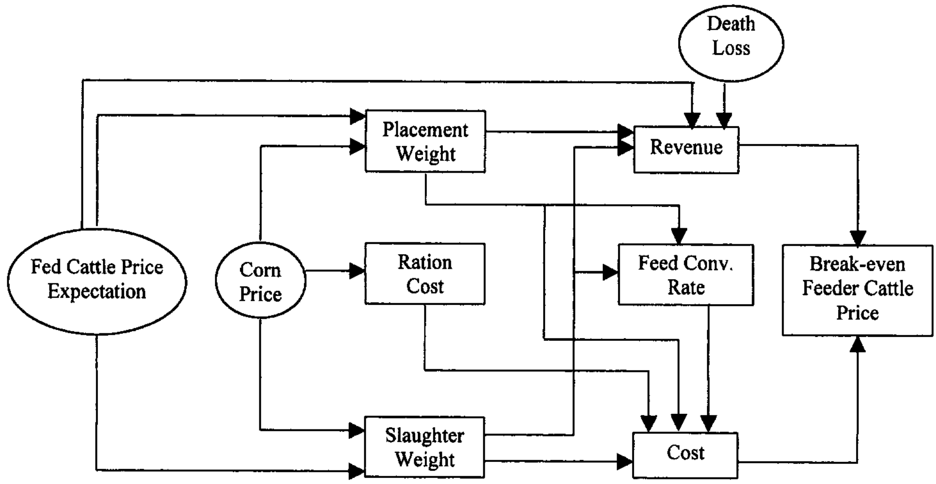
feeder-calf prices to a change in the price of corn. Fox reports that a \$1/bu increase in the price of corn results in a \$7–\$10 decrease in the value of calves and feeder cattle. Similarly, Maday writes that a \$0.10/bu increase in corn price will result in a \$0.75/cwt drop in feeder prices. Results such as these can be obtained from the break-even budget of Table 1. Given the budget parameters in Table 1, a one-dollar increase in the corn price drops the break-even feeder price by \$7.50/cwt.

The fundamental problem with deriving estimates of a corn price multiplier from break-even budgets is that the budgets assume independence of corn prices and technical feeding parameters, specifically placement weight, slaughter weight, and feed-conversion rates. In other words, in deriving a multiplier value, technical factors are held constant regardless of the corn price.

Figure 1 outlines the structure of a dynamic model where placement weight, slaughter weight, and feed-conversion rates are assumed/specified to respond to corn price. The "flow-through" impact of this assumption upon cost and revenue and eventually the break-even feeder cattle price are also depicted.

There are two fundamental reasons to believe that placement weight, slaughter weight, and feed-conversion rates are assumed/specified to respond to corn price changes. First, at high corn prices other grains (e.g., wheat) may be used in the ration to hold feed costs down. Second, placement and slaughter weights will be adjusted in response to corn price changes. As corn price increases, more weight will be put on calves with forages (e.g., via grazing which, in effect, results in grass being substituted for corn), leading to higher placement weights (Parsons). Placement weight adjustments will also impact feed-conversion rates (Lofgreen and Garrett); that is, the greater the placement weight, the poorer the conversion rate, *ceteris paribus*. Finally, slaughter weights will change in response to two opposing forces: a) higher corn prices cause the marginal cost of gain to equate to marginal revenue at a lighter weight, but b) higher placement weights cause the weight at which cattle will grade choice to increase (Fox and Black). This would typically be expected to increase slaughter weights (Owens, Dubeski, and Hanson). The net effect of these two opposing forces is that while slaughter weights increase with placement weights, they do not increase as fast as placement weights; thus cattle placed at heavier weights gain fewer total pounds while on feed than those placed at lighter weights (Vaage *et al.*).

The objective of the research presented here is to provide a more complete understanding of the relationship between corn and feeder-calf prices than is currently reflected in popular corn price multipliers based on *ceteris paribus* break-even budgets. Such understanding, when extended to cattle producers and feeders, should allow them to respond more effectively to corn price changes with respect to production and pricing decisions. In addition, the fuller understanding that results from this study related to the relationship between technical feeding parameters (placement weight, slaughter weight, and feed conversion) and corn price changes should permit the development of more accurate and complete management/decision-making guidelines. In order to accomplish these objectives, an



Note: Variable names enclosed in ovals are assumed to be exogenous, and those enclosed in rectangles are assumed to be endogenous.

Figure 1. Conceptual model of the recursive system described by break-even feeder cattle price calculations

econometric model of the recursive system of Figure 1 will be estimated.

Background

The basic budget calculation giving profit per head (Π) from feeding cattle can be written as follows:

$$(1)\quad \Pi = [(FED \cdot SW)(1 - DL)] - [(FC \cdot PW) + (SW - PW)COG],$$

where *FED* is the price received for fed cattle, *SW* is the slaughter weight of fed cattle, *DL* is death loss as a percentage of the number of cattle fed,[1] *FC* is the price paid for feeder cattle at placement, *PW* is the placement weight of feeder cattle, and *COG* is cost of gain per pound.

[1] This method of incorporating death loss into the equations assumes that all feeding costs are incurred by the cattle which die—in other words, that they die on the last day of feeding. This is obviously an unlikely assumption; however, death loss is included in this model only for conceptual completeness. In addition, it was found in estimating the break-even model that eliminating death loss completely results in only very small changes in the magnitude of the revenue variable.

COG is determined by the cost of the ration and the amount of that ration that is required to put a pound of gain on the animal. Thus, *COG* is summarized in the following mathematical relationship:

$$(2)\quad COG = RC \cdot CONV,$$

where *RC* is the ration cost per pound and *CONV* is the feed-conversion rate.

An equation which shows the relationship between ration cost and the associated break-even feeder cattle price can be derived from equation (1) if three things are done: a) Π is set to zero, b) *COG* is replaced by (2), and c) the equation is solved for *FC*. The resulting equation is

$$(3)\quad FC = [((FED \cdot SW)/PW)(1 - DL)] - [((SW - PW)CONV \cdot RC)/PW],$$

where all variables are as previously defined. Given equation (3), all that is required to determine the relationship between corn price and feeder cattle price is to define the relationship between corn price and ration cost.

Feeder-Calf Price Model Specification

Equation (3) is a more concise presentation of the break-even calculations of Table 1. It is thus a mathematical representation of the recursive system in Figure 1. The plan of this research is to estimate an econometric model derived directly from equation (3) that will capture all of the essential elements of the system which the equation represents.

The following equation provides a starting point for estimation of the break-even model:

$$(3') \quad FC_t = [((FED^e_{t+f} \cdot SW^e_{t+f})/PW^e_{t+f})(1 - DL^e_{t+f})] - [((SW^e_{t+f} - PW^e_t)CONV^e_{t+f} \cdot RC^e_{t+f}) \div PW^e_{t+f}],$$

where FC_t is the feeder-cattle break-even price at time t; FED^e_{t+f} is the expectation at time t of the fed cattle price at time t+f, with f representing the length of the feeding period; SW^e_{t+f} is expectation at time t of slaughter weight at time t+f; PW^e_{t+f} is the expected weight of cattle placed at t for slaughter at t+f; DL^e_{t+f} is the expectation at time t of death loss for cattle slaughtered at time t+f; $CONV^e_{t+f}$ is the expectation at time t of the dry matter feed-conversion rate of cattle slaughtered at time t+f; and RC^e_{t+f} is the expectation at time t of the average ration cost per pound for cattle slaughtered at t+f.

The multiplicative relationships between the variables in equation (3′) indicate that a model with strictly linear relationships between ration cost, live cattle futures price, and feeder-cattle price is not the most appropriate representation of the feeder-cattle market (e.g., see Buccola). A more appropriate model would use the expected cost and revenue components of the break-even feeder-cattle price equation as explanatory variables. Such a model would preserve the multiplicative relationships and also incorporate the information obtained in the expected values of the technical feeding parameters. The right-hand side of equation (3′) can be broken into expected revenue (REV^e_{t+f}) and expected cost ($COST^e_{t+f}$) components as follows:

$$(4) \quad REV^e_{t+f} = ((FED^e_{t+f} \cdot SW^e_{t+f})/PW^e_{t+f}) \times (1 - DL^e_{t+f}), \quad \text{and}$$

$$(5) \quad COST^e_{t+f} = ((SW^e_{t+f} - PW^e_t)CONV^e_{t+f} \cdot RC_{t+f}) \div PW^e_{t+f}.$$

When (4) and (5) are considered within the context of the conceptual framework established with Figure 1, it becomes clear that some means of obtaining placement weight, slaughter weight, conversion rate, and ration cost expectations is required; and that those expectations should be conditioned by corn price. The problem deriving such expectations is that data on these factors for use in modeling is not readily available.

Professional Cattle Consultants (PCC) of Weatherford, Oklahoma is a consulting firm that compiles performance information from approximately one hundred major feedlots throughout the dominant cattle feeding areas of the United States. The feedlots reporting to PCC collectively produce over 25 percent of the fed cattle in the United States. While individual feedlot data is confidential, aggregate monthly data for placement weights,[2] slaughter weights, feed-conversion rates, and death loss were available for use in this research (*PCC Newsletter*). Data for the period 1986–1995 were used to develop models to obtain expected values for the technical parameters appearing in equations (4) and (5). In addition to this PCC data, cash feeder-calf prices from Oklahoma City, cash corn prices from Omaha, Nebraska and live cattle futures prices from the CME are used in the estimation discussed below. Table 2 gives a complete description of the data used in this study.

Placement Weight, Slaughter Weight, Ration Cost, and Conversion Rate Expectations

Placement weight is treated as an endogenous variable because at the time cattle are placed

[2] PCC does not report the weight of cattle placed each month. Rather, they report from the closeout sheet of pens slaughtered the average placement weight of cattle slaughtered each month. They also report average number of days on feed for cattle slaughtered. Thus, placement weights for a given month can be deduced retroactively.

on feed, the buyer/owner has a choice of what weight of cattle to buy/place on feed. Placement weight is thus subject to variation due to economic conditions. Following the logic of Figure 1, placement weight was specified as a function of the corn/live cattle price ratio, a trend variable, and sine/cosine seasonality variables. The estimated equation is given below with standard errors in parentheses:

$$(6) \quad \begin{aligned} PW_t = {} & \underset{(60.239)}{348.98} + \underset{(0.085)}{0.498}\, PW_{t-1} \\ & + \underset{(227.006)}{484.871}\, (C/LC)_t + \underset{(0.033)}{0.100}\, TIME \\ & - \underset{(1.542)}{14.288}\, SIN12 + \underset{(1.329)}{10.530}\, SIN6 \\ & + \underset{(3.234)}{15.742}\, COS12 + \underset{(1.621)}{3.181}\, COS6; \end{aligned}$$

$$R^2 = 0.9007 \quad \text{and} \quad \text{F statistic} = 130.941,$$

where PW_t is placement weight at time t, $(C/LC)_t$ is corn price at time t ÷ live cattle futures price at time, *TIME* is a trend variable, *SIN12* and *SIN6* are sine variables with 12- and 6-month cycles respectively, and *COS12* and *COS6* are cosine variables with 12- and 6-month cycles respectively. Sine and cosine variables model the seasonality of the data series. As expected, a positive relationship was found between placement weight and corn price.

Slaughter weight expectations are derived from a similar partial adjustment model. Slaughter weight is modeled as a function of placement weight so the relationship between slaughter weight and corn price postulated in the conceptual framework (Figure 1) is an indirect one. A time-trend variable and sine/cosine seasonality variables identical to those of the placement weight expectation model are also included in the model. Placements of cattle on feed were also expected to affect slaughter weights since feedlots can (to some degree) adjust the timing of fed cattle marketings as a means of managing inventory (Bacon). The estimated equation is given below with standard errors in parentheses:

$$(7) \quad \begin{aligned} SW_{t+f} = {} & \underset{(78.178)}{245.137} + \underset{(0.067)}{0.630}\, SW_{t+f-1} \\ & + \underset{(0.074)}{0.224}\, PW_t + \underset{(0.070)}{0.336}\, TIME \\ & - \underset{(1.746)}{16.575}\, SIN12 + \underset{(1.401)}{2.707}\, SIN6 \\ & - \underset{(2.905)}{9.076}\, COS12 + \underset{(1.195)}{6.127}\, COS6 \\ & - \underset{(0.004)}{0.011}\, DPLACE_t; \end{aligned}$$

$$R^2 = 0.9647 \quad \text{and} \quad \text{F statistic} = 341.678,$$

where SW_{t+f} is the slaughter weight at time t+f, PW_t is the placement weight of those cattle at time t, $DPLACE_t$ is the change from the previous year in placements of cattle on feed at time t, and other variables are as previously defined. A Durbin-h test revealed no significant autocorrelation in either of these two models.

According to equation (7), slaughter weight increases with placement weight. This finding is consistent with the biological nature of cattle feeding. A certain amount of gain must come from grain feeding if cattle are to grade choice. For this reason, higher placement weights generally result in higher slaughter weights and vice versa; however, sufficient latitude exists within the placement weight/slaughter weight relationship to allow significant adjustment to be made and the cattle still grade choice. Increased placements are indicated to have a negative impact on slaughter weight, implying that when placements are up (down), those calves will—at the end of the feeding period—be slaughtered at a lower (higher) weight. This result is consistent with feedlots adjusting the timing of marketing to help manage their inventory of cattle in the feedlot.

A ration-cost series was not available from PCC for use in estimating a ration-cost model; however, using the relationship defined in equation (2), an implied ration-cost series was constructed using PCC data on cost of gain and feed-conversion rate. The cost of gain reported by PCC will reflect more than just feed costs. Expenses such as interest, veterinary

Table 2. Description of Variables Used in Weekly Feeder-Cattle Price Model

Variable	Description	Mean	Std. Dev.
Dependent:			
FC	OKC cash feeder-calf price ($/cwt)[a]	79.53	9.95
Independent:			
CORN	Omaha cash corn price ($/bu)[b]	2.23	0.36
LC	Live cattle futures price 140 days forward ($/cwt)[c]	68.73	6.30
PW	Placement weight[d]	738.89	27.57
SW	Slaughter weight[d]	1,169.71	40.86
CONV	Feed conversion[d] (lbs dry matter/lb gain)	6.536	0.264
RC	Implied ration cost[d] (reported cost of gain ÷ feed-conversion rate	0.077	0.006

[a] Source: Oklahoma Dept. of Agriculture.
[b] Source: Livestock Marketing Information Center.
[c] Source: CME daily closing price.
[d] Source: Professional Cattle Consultants, Weatherford, OK.

charges, and yardage will be included in cost of gain; however, the bulk of the reported cost of gain figure will be comprised of feed costs. The implied ration-cost series was thus considered to be a reasonable proxy for an actual series and was used in the estimation presented here. The ration-cost model is given here with standard errors in parentheses:

$$(1)\quad \begin{aligned} RC_{t+f} = {} & \underset{(0.0012)}{0.035818} + \underset{(0.0006)}{0.010}\ CORN_t \\ & + \underset{(0.1207)}{0.121}\ SBM_t \\ & + \underset{(0.06 \times 10^{-6})}{1.01 \times 10^{-4}}\ TIME \\ & + \underset{(0.0002)}{7.45 \times 10^{-4}} SIN12 \\ & + \underset{(0.0002)}{1.13 \times 10^{-4}} SIN6 \\ & - \underset{(0.0002)}{0.002}\ COS12 \\ & - \underset{(0.0002)}{9.71 \times 10^{-5}} COS6, \end{aligned}$$

where RC_{t+f} is the average ration cost over the feeding period for cattle slaughtered at t+f, $CORN_t$ is the corn price at t, and SBM_t is the soybean meal price per pound at t, and other variables are as previously defined.

A Durbin-Watson test revealed significant autocorrelation in this model. A partial adjustment model was estimated in an attempt to correct the autocorrelation; however, a Durbin-h test for autocorrelation was still significant. Predictions from the full adjustment model were used since parameter estimates are still unbiased and consistent. Signs on the corn and soybean meal variables are positive, which is consistent with expectations.

An attempt was made to estimate feed conversion as a function of placement and slaughter weights and seasonality. However, in both partial and full adjustment specifications of the model, the coefficient on slaughter weight was statistically significant and negative, indicating that as cattle get heavier, conversion rate improves—a theoretically indefensible result. It appears that pronounced seasonal patterns and purely random effects (such as extreme weather) dominate any other factors influencing feed-conversion rate. To provide a seasonal expectation of feed-conversion rates, average feed conversion figures were calculated by month using data for the entire period of the study. These monthly average conversion rates were used in computing the cost and revenue variables of the break-even equation.

An actual death-loss series was not used in generating the revenue variable. The only death-loss figure available for the entire period of the study was average death loss per month. A more appropriate figure would have been average death loss per pen of cattle over the feeding period of the pen; however, those figures were not available. An average death loss per pen of 0.87 percent was used rather than an actual death loss data series. This value corresponds to the average death loss per pen in 1994 and 1995, the two years for which these data on death loss per pen were available.

For the purpose of estimating the weekly feeder-cattle price model, calves are assumed to be on feed 140 days. The fed-cattle price expectation referred to in Figure 1 is represented by the live cattle futures price 140 days forward. Live cattle prices were the futures price that producers would most likely use to hedge their cattle. For example, if the expected finish date was in May, prices were taken from the June live-cattle contract. If the expected finish date was in June, prices were taken from the August contract because hedgers would not be inclined to take a position that they would need to maintain into the contract expiration month.

The fact that the model specified here specifically allows for placement weights to change over time must be recognized in the collection and specification of an appropriate feeder-cattle price series. Feeder-cattle prices are reported as the average price received over specified weight ranges. To use a price series from just one weight range would reflect the general rise and fall of feeder-cattle prices over time, but would not allow for price changes due to changes in the weight of feeder-cattle being placed on feed. In general, a strong negative relationship exists between feeder-cattle prices per hundredweight and the weight of feeder cattle; that is, as feeder-cattle weights increase, the price per hundredweight declines. Over the period under consideration here, the price for 700–800 pound feeder cattle averaged \$3.24/cwt less than the price for 600–700 pound feeder cattle.

To address the problem of changing feeder-cattle prices with weight, a "weight-continuous" series of feeder-cattle prices was developed by linearly interpolating between the discrete weight point prices given by the reporting of average prices received over a given weight range. From 1985 to 1991, average prices for 600–700 pound feeder cattle and for 700–800 pound feeder cattle were reported for the Oklahoma City market. If it is assumed that the average price for 600–700 pound feeders most accurately represents the price for a 650-pound animal and the average price for 700–800 pound feeders represents the price for a 750-pound animal, then the price for any weight between 650 and 750 pounds can be imputed by linear interpolation. For example, if the price of 600–700 pound steers was \$82/cwt, and the price for 700–800 pound steers was \$80/cwt, the following prices by weight would be deduced from linear interpolation: 650 pounds—\$82.00; 675 pounds—\$81.50; 700 pounds—\$81.00; 725 pounds—\$80.50; 750 pounds—\$80.00. Equation (9) expresses the interpolation process algebraically:

$$(9)\qquad AFC = FC67 - [((PW - 650)/100) \times (FC67 - FC78)],$$

where *AFC* is the derived weight continuous "adjusted feeder price" value, *PW* is placement weight, *FC67* is the reported average price for 600–700 pound feeder steers, and *FC78* is the reported average price for 700–800 pound feeder steers. After 1991 feeder cattle prices at Oklahoma City began to be reported for 50-pound weight increments instead of 100-pound increments. The same basic procedure was used in adjusting feeder prices except one first had to determine which weight range was appropriate and then interpolate in the same manner as done in equation (9) but over a 50-pound weight range instead of a 100-pound weight range.

Having defined equations (4) through (9), we can return to equation (3′) and complete the specification of the feeder-cattle price model to be estimated.

$$(10)\qquad AFC_t = f(AFC_{t-1}, REV^e_{t+f}, COST^e_{t+f}, SEASON, CYCLE),$$

where AFC_t is the adjusted feeder cattle price at time t, REV^e_{t+f} is expected feeding revenue as defined in equation (4), $COST^e_{t+f}$ is expected

Table 3. Estimated Parameters for the Break-even Feeder-Calf Price Model

Independent Variables	Partial Adjustment Estimated Coefficients	S. E.	Long-Run Estimated Coefficients	S. E.
FC_{t-1}	0.724**	0.023		
COST	−40.821**	5.153	−147.847**	18.665
REV	0.327**	0.029	1.185**	0.104
$SEAS_{COS12}$	0.137	0.114	0.495	0.411
$SEAS_{COS6}$	0.383**	0.088	1.387**	0.317
$SEAS_{SIN12}$	−0.013	0.091	−0.046	0.331
$SEAS_{SIN6}$	−0.112	0.083	−0.407	0.301
$CYCLE_{COS132}$	−0.182	0.230	−0.661	0.834
$CYCLE_{COS66}$	−0.287*	0.115	−1.041*	0.416
$CYCLE_{SIN132}$	1.363**	0.440	4.936**	1.593
$CYCLE_{SIN66}$	0.568**	0.207	2.058**	0.750
TIME	0.008**	0.002	0.029**	0.009
Intercept	−3.528	1.918	−12.776	6.946
F statistic	1,966.723**			
R^2	0.981			
F statistic on cosine and sine seasonal variables			5.250**	
F statistic on cosine and sine cycle variables			3.089*	

Note: The number of observations was 474. Single asterisks denote significance at the 5% level; double asterisks denote significance at the 1% level. Subscripts on season and cycle variables define the type of variable (cosine or sine), with numbers indicating period length in months.

feeding cost as defined in equation (5), *SEASON* is a set of sine/cosine variables based on a 12-month seasonal pattern, and *CYCLE* is a set of sine/cosine variables based on an 11-year cattle cycle.

To arrive at the feeder-calf price equation, (6), (7), and (8) were substituted into (4) and (5). Equations (4) and (5) enter (10) directly following the logic established in (3′). A positive sign is expected on the revenue component, and a negative sign is expected on the cost component. The effect of corn prices enters the cost component through ration cost as is shown in (3′) as well as (5). Corn price also affects the revenue component of (3′) through placement weight (*PW*) and slaughter weight (*SW*) variables. Equation (6) for placement weight includes corn price as a variable, and, in turn, equation (7) for slaughter weight contains placement weight as a variable.

In short, equations (4) through (10) represent an econometric model of the recursive system illustrated in Figure 1. The econometric model differs from the conceptual framework in three minor respects. First, seasonal average conversion rates rather than a conversion rate expectation conditioned by placement and slaughter weights have been used in calculating revenue and costs. Second, the impact of corn and fed cattle prices on slaughter weight occurs indirectly through placement weight changes. Third, seasonality and long-term cycle variables have been included in the econometric estimation.

Break-even Feeder-Calf Price Model Results and Implications

Results of the feeder-calf price model are presented in Table 3. A Durbin-h test revealed no significant autocorrelation, and Harvey and Glejser tests revealed no significant heteroskedasticity (Greene).

The economic significance of the break-even model is that it allows for a determination of how changes in placement weight, slaughter weight, and feed conversion affect the relationship between corn and feeder-calf prices. Rule-of-thumb estimates are certainly consistent with break-even budgeting; however, they are not consistent with the break-even model presented in Table 3. Because of the multiplicative relationships between ration cost, feed conversion, placement weight, and slaughter weight, the effect of corn price on feeder cattle price will not be constant. A more precise estimate of the effect of corn price on cattle price can be found in the first derivative of the long-run break-even equation in Table 3 with respect to corn price (noting that equation (8) has been substituted into equation (5)):

$$(11)\quad \partial FC/\partial CORN = -147.857(0.0105(SW - PW)CONV) \div PW.$$

Note that feed conversion, placement weight, and slaughter weight remain in the first derivative expressed in equation (11), indicating that the effect of corn price on cattle price varies with these factors. Feed conversion, slaughter weight, and placement weight are themselves quite variable—seasonally as well as from year to year. The key point is that the corn price multiplier will change in response to—or is "conditioned" by—changes in placement weight, slaughter weight and feed conversion. Thus, it is inaccurate to consider the relationship between corn and feeder prices as constant, as the popular rules of thumb imply. Seasonality of the technical factors alone will result in noticeable changes in the multiplier. In addition, long-term changes in technical factors due to technological and institutional changes in the feeding sector will cause the multiplier to change over time. Even more importantly, slaughter weight and placement weight will adjust to corn price changes as indicated in equations (6) and (7). A static multiplier derived from a break-even budget cannot account for the dynamics of this adjustment process.

Derivation of a Dynamic Corn Price Multiplier

To derive a multiplier that will capture the system-wide effects of a corn price change, a six-equation dynamic simulation model was constructed based on equations (6) through (8) for placement weight, slaughter weight, and ration cost respectively; equations (4) and (5) which calculate revenue and cost to be used in the feeder cattle price equation; and the feeder cattle price equation (10) itself. The short-run partial-adjustment coefficients that are reported in Table 3 were used to define equation (10).

The model was simulated in the recursive sequence depicted in Figure 1; that is, placement weights and slaughter weights were calculated first along with ration cost and then used to derive revenues and costs as defined by equations (4) and (5). Revenues and costs were in turn used in equation (10) to calculate the feeder price. The dynamics of the model follow from the fact that the solution values found for placement weights, slaughter weights, and feeder-cattle prices were then lagged one period and fed back into their respective equations and the system of equations solved again for the next period. This process was repeated until the feeder-cattle price solution value stabilized. Specifically, all exogenous variables were set to their mean values and held constant throughout the simulation, except for corn price. In Period 0, corn price was set at its mean, but in period 1, corn price increased by \$0.25/bu. Following the increase in corn price, approximately 69 weeks of simulated recursive solutions were required for the model to stabilize. Results of the simulation are presented in Table 4.[3,4]

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[3] In viewing Table 4 it should be noted that the simulated values for placement weight and slaughter weight change only every fourth week as opposed to feeder cattle prices which change weekly. This is because placement weight and slaughter weight models used monthly data, and the feeder-cattle price equation used weekly data. Simulation of these two time lengths was accomplished by only allowing the lagged values for placement weight and slaughter weight to be updated every fourth iteration, instead of every iteration as was the case for the lagged feeder cattle price variable.

[4] Empirical validation of the simulation model was achieved by checking to ensure that placement weight, slaughter weight, and feeder-cattle price equations, when simulated independently with all variables held constant at their mean (except corn price), reached the same values at equilibrium as were found when each equation was solved using its respective long-run co-

Table 4. Simulated Adjustments to $0.25 Corn Price Increase

Week	Corn Price	Ration Cost	Feeder Price	In-wgt.	Out-wgt.	Multiplier	% of Total Adjustment Completed
0	2.227	0.0765	79.53	738.89	1,169.71		
1	2.477	0.0790	79.14	740.65	1,170.11	−1.57	25.59%
2	2.477	0.0790	78.85	740.65	1,170.11	−2.71	44.13%
3	2.477	0.0790	78.65	740.65	1,170.11	−3.54	57.54%
4	2.477	0.0790	78.50	740.65	1,170.11	−4.14	67.26%
5	2.477	0.0790	78.36	741.53	1,170.55	−4.68	76.12%
6	2.477	0.0790	78.26	741.53	1,170.55	−5.07	82.53%
7	2.477	0.0790	78.19	741.53	1,170.55	−5.36	87.18%
8	2.477	0.0790	78.14	741.53	1,170.55	−5.57	90.54%
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
12	2.477	0.0790	78.02	742.19	1,170.93	−6.06	98.52%
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
Equil.	2.477	0.0790	77.99	742.40	1,171.22	−6.15	100.00%

Note: Equilibrium parameter values were achieved in week 69.

Simulation results indicate that over three-fourths of the adjustment to the corn price change is achieved in five weeks. The change in placement weight between the new equilibrium and the initial placement weight is 3.51 pounds and the change in slaughter weight is 2.13 pounds. The simulated change in feeder cattle price is a $1.54 decline. When divided by $0.25, this results in a dynamic system corn price multiplier of −6.15, which is considerably lower than the budget-derived popular press multipliers of around −7.50.

Because the ultimate value of the multiplier will be influenced by the initial values for placement weight, slaughter weight, and feed-conversion rate, it appears to be misleading to report a single value for the corn price multiplier—even if that value is derived from a simulation of a recursive system which lets technical parameters adjust to the corn price change. Table 5 provides an array of multiplier values derived from dynamic simulation of the recursive system. This table illustrates how the multiplier is influenced by initial values of the technical parameters.

Conceptually, popular press multipliers are not really comparable to the dynamic system multiplier since popular press multipliers are derived by changing corn price alone in the break-even budget. To derive a multiplier from the budget model in Table 1 that is comparable to the dynamic system multiplier, it is necessary not only to change the corn price in the budget, but also to change placement weight and slaughter weight by the amounts which equations (7) and (8) indicate they should change in response to a corn price change. To illustrate this point, a $0.25 corn price rise from the mean corn price was again considered. As determined in the simulation, the corn price change results in a long-run increase in placement weight of 3.51 pounds and a long-run increase in slaughter weight of 2.13 pounds. If those weight changes (from initial mean values) are budgeted along with the $0.25 corn price increase, the resulting dynamic budget multiplier is −8.39. The dynam-

efficients and mean values for all variables (except corn price, which was set at $0.25 above its mean). For the purpose of this validation of the feeder-calf price equation, placement weight and slaughter weight were held constant at their mean rather than being allowed to dynamically adjust to the simulated corn price change. Long-run coefficients were derived by multiplying the parameters in each equation by $1/(1-\alpha)$, where α is the parameter on the lagged dependent variable in each respective equation.

Table 5. Dynamic Corn/Feeder-Cattle Price Multiplier at Different Initial Placement Weight, Slaughter Weight, and Feed-Conversion Levels

Feed Conversion	Slaughter Weight 1,100	1,150	1,200	1,250
	Placement Weight = 675			
6.25	−6.47	−7.22	−7.98	−8.73
6.50	−6.66	−7.44	−8.22	−8.99
6.75	−6.85	−7.65	−8.46	−9.26
7.00	−7.04	−7.87	−8.70	−9.52
	Placement Weight = 700			
6.25	−5.86	−6.58	−7.30	−8.03
6.50	−6.03	−6.78	−7.52	−8.27
6.75	−6.20	−6.97	−7.74	−8.52
7.00	−6.37	−7.17	−7.96	−8.76
	Placement Weight = 725			
6.25	−5.29	−5.99	−6.68	−7.38
6.50	−5.54	−6.17	−6.89	−7.61
6.75	−5.60	−6.34	−7.09	−7.83
7.00	−5.75	−6.52	−7.29	−8.05
	Placement Weight = 750			
6.25	−4.77	−5.44	−6.11	−6.78
6.50	−4.90	−5.60	−6.29	−6.99
6.75	−5.04	−5.76	−6.48	−7.19
7.00	−5.18	−5.92	−6.66	−7.40
	Placement Weight = 775			
6.25	−4.28	−4.92	−5.57	−6.22
6.50	−4.40	−5.07	−5.74	−6.41
6.75	−4.52	−5.21	−5.91	−6.60
7.00	−4.65	−5.36	−6.07	−6.79

ic budget multiplier is larger than the popular press multiplier because lower net revenue is divided by a higher placement weight in arriving at the break-even feeder price.

The dynamic system multiplier is much lower than this comparable dynamic budget multiplier. This is due to the interaction of placement weight, slaughter weight, and ration cost changing and in turn impacting the dynamics of the feeder-cattle price adjustment process. As placement weight rises in response to corn price, total costs decrease since less weight is being put on calves with grain. In addition, an increase in placement weight also causes slaughter weight to increase, which causes gross revenue to rise. On the other hand, the increase in ration cost in response to the corn price increase results in higher costs. It is important to note, though, that ration cost does not increase at the same rate as corn price. This is the critical difference between the simulation and the break-even budget. As a result, in the simulation the increased cost impact of a rise in corn price is offset to a degree by the lowered cost/increased revenue impact. Thus, while the increase in corn price does result in a decrease in feeder-cattle prices, that decrease is not as severe as budgeting results would predict. The fact that the effect of a corn price change on feeder-calf prices is mitigated by changes in feeding programs is reflected in a dynamic corn price multiplier that is much smaller than the break-even multiplier.

Table 6. Alternative Corn Price Multipliers

Popular Press Multiplier Typical multipliers found using static budgets. See Table 1.	−7.50
Simulated Dynamic System Multiplier Derived by simulation of the system depicted in Figure 1 and as estimated with equations (4), (5), (6), (7), (8), and (10).	−6.15
Dynamic Budget Multiplier Derived using the budget format of Table 1 but with changes in the placement and slaughter weight in response to corn price as indicated by equations (6) and (7).	−8.39

Summary and Comparison of Multipliers Derived

In the previous sections three corn price multipliers have been derived. They are summarized in Table 6. Initially, it was reported that many popular press articles derived and reported a multiplier of about −7.50. Derivation of this multiplier is shown in Table 1. Two additional multipliers were calculated to consider the dynamic/system-wide nature of the response to corn price. First, to determine a dynamic multiplier for the system of equations depicted in Figure 1 and represented by equations (4) through (8) and (10), the system of equations was dynamically simulated until it reached equilibrium. The resulting multiplier was a −6.15. Last, to inject the placement and slaughter weight changes into the static budget multiplier calculations of Table 1, equations (6) and (7) were solved for their long-run equilibrium response to a $0.25 corn price change. The indicated placement and slaughter weight changes were then reflected in the budget calculations as opposed to maintaining these variables at their mean data set values. The resulting multiplier was found to be −8.39.

In summary, the econometrically derived multiplier indicates that feeder-cattle prices will decline by as much as $2/cwt less for each $1 increase in corn prices than the budget-derived multipliers indicate. Expressed in percentage terms (and using −7.5 as a base multiplier) this amounts to roughly a 25 percent smaller response. Of course, initial placement weight, slaughter weight, and feed-conversion rate values will have a significant impact on the response (see Table 5). The modeling done here does not provide an exact explanation of why the difference between budgeted and statistically derived response expectations occurs; however, it does suggest two important things: a) that the budgeting approach fails to capture the full dynamics of the adjustment process, and b) that it fails to consider adjustments in rations in response to corn price increases. In addition, the conceptual approach for determining the budget multiplier and the econometrically estimated multiplier are very different. The budget multiplier is not based on historical data (except perhaps to determine the mean values used). Thus it describes actual market behavior only to the degree that the market responds as theoretically hypothesized in the budgeting process. The econometric multiplier, however, is based on actual market behavior (data) and is thus an estimate of actual market behavior.

Summary and Conclusions

In this study, a regression model was specified which was derived directly from the break-even feeder price budget. The model contained as explanatory variables a revenue variable (consisting of a slaughter weight times the appropriate futures price for live cattle) and a cost variable (incorporating estimates of placement weights, pounds of gain, feed-conversion rates, and corn prices to proxy feeding costs). These two variables together with seasonal and cyclical variables were regressed against feeder cattle prices.

Results indicate that feeder-calf prices are less responsive to changes in corn price than popular rules of thumb imply. Adjustments to cattle feeding programs serve to mitigate the impact of corn price changes on feeder-calf prices. Rule-of-thumb characterizations of the corn/feeder-calf price relationship are unable to account for these adjustments.

Changes to feeding programs in response to corn price changes involve adjusting the placement weight of cattle placed on feed and adjusting feedlot ration composition. Industry average placement weights were found to rise by approximately 14 pounds per dollar of increase in corn price. This rise in placement weights was further found to effect an increase in slaughter weights of between 8 and 9 pounds per dollar of increase in corn price. While ration cost also goes up with corn price, it does not go up as quickly. Thus, feeding cost increases can be more than offset by the cost savings associated with weight adjustments, resulting in a considerably smaller effect of corn prices on feeder prices than static break-even budget analysis would imply when only corn price is changed in the budget.

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