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Cattle - Prices

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Weight, Sex, and Feeder Cattle Price Differentials: A Theoretical and Empirical Analysis

by

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ABSTRACT

A model is developed which helps explain the impact of weight, sex, and other animal characteristics on feeder cattle prices. Theoretical results are then compared with feeder price differentials observed over two cattle cycles. The influence of feed prices and fed cattle prices on these differentials is emphasized.

Weight, Sex, and Feeder Cattle Price Differentials: A Theoretical and Empirical Analysis

One of the difficulties faced by agricultural economic price analysts is the great variety of subclasses identifiable within commodity categories. Beef cattle price analysts face a particularly difficult problem in this regard. In addition to spatial, temporal, grade, and variety distinctions inherent in most agricultural commodities, cattle traders often discriminate sharply on the basis of weight, age, and sex. The present paper develops a theoretical and empirical framework for understanding the impact of market conditions on price differentials among classes of feeder cattle. The approach may assist in the extension of single feeder class price study results to other feeder classes, and deepen our insight into the complex markets for feeder cattle generally.

Theoretical Framework

It is convenient to distinguish between animal weight, a continuous variable, and discrete characteristics such as breed, grade, sex, and age (calf/yearling). Price differences among feeder classes may be summarized by variations among breeds, grades, sexes, and ages in feeder price-weight relationships. These variations have their basis in profit functions faced by stocker sellers and feedlot buyers of feeder cattle. The per head profit π_f earned by a feeder buyer may be expressed as:

(1) $\pi_f = P_t(W_t,D)W_t - r_d[W_t-w_r]f(w_r,D) - [W_t-w_r]g(w_r,D)/ADG - HC_f - p_r w_r$,

in which

W_t, w_r = weights of fed and feeder animals respectively, in cwt;

r_d = price of feed ration, in \$/Mcal metabolizable energy (ME);

D = a discrete breed, grade, age, and sex description;

HC_f = per head costs of animal introduction to feedlot, in \$;

ADG = average daily gain under feed, in cwt;

$f(w_r,D)$ = feed efficiency, in Mcal/cwt gain;

$g(w_r,D)$ = daily nonfeed cost of animal maintenance, in \$;

$P_t(W_t,D)$ = fed cattle price, in \$/cwt;

p_r = feeder cattle price, in \$/cwt.

The right hand side of (1) consists respectively of per head sale revenue, feed cost, daily basis nonfeed cost, per head basis nonfeed cost, and feeder animal cost. At the time of feeder animal purchase, the feedlot generally has in mind a target fed weight W_t, average daily gain ADG, and slaughter grade; but fed price P_t, feed price r_d, and feed efficiency f are expected values of random variables. If there is no profit or loss, (1) is set equal to zero and the expected breakeven feeder price p_r is

(2) $$p_r = P_t(W_t,D)W_t/w_r + r_d[1-W_t/w_r]f(w_r,D) + [1-W_t/w_r]g(w_r,D)/ADG - HC_f/w_r.$$

Expression (2) is a function of, among other things, feeder weight w_r and discrete characteristic set D. The relationship of p_r to w_r in (2) is referred to as the buyer's breakeven price-weight line. The first derivative of this expression with respect to weight reflects the change in breakeven price caused by a marginal weight increase (price-weight gradient or slope):

(3) $$dp_r/dw_r = -P_t(W_t,D)W_t/w_r^2 + r_dW_tf(w_r,D)/w_r^2 + r_d[1-W_t/w_r]f_{wr}(w_r,D) + [W_t/w_r^2][g(w_r,D)/ADG] + [1-W_t/w_r]g_{wr}(w_r,D)/ADG + HC/w_r^2.$$

Further differentiation w.r.t. weight specifies the concavity or convexity of the price-weight line.

There is good evidence (National Research Council) that slopes $f_{wr}(w_r,D)$ and $g_{wr}(w_r,D)$, respectively representing marginal losses in feed efficiency and marginal increases in daily nonfeed maintenance costs as weight rises, are positive. Hence the first r.h.s. term in (3) is negative and the rest alternate in sign; the net sign and value of (3) depend upon relative absolute levels of these terms.

Expected or observed market prices affect the price-weight gradient. For example the algebraic value of (3) falls with increases in fed price P_t since

(4) $d(dp_r/dw_r)/dP_t = - W_t/w_r^2 < 0.$

Expression (4) indicates that as fed cattle prices increase, breakeven feeder cattle prices increase more quickly, or decrease more slowly, with reductions in initial feeder weight. The impact of changes in feed price r_d on the feeder price-weight gradient,[1/]

(5) $d(dp_r/dw_r)/dr_d = [W_t/w_r^2]f(w_r,D) + [1-W_t/w_r]f_{wr}(w_r,D),$

is, however, indeterminate in sign since the first r.h.s. term is positive and the second negative. Depending upon the magnitude f and slope f_{wr} of the feed efficiency function, feed price increases may cause the feeder price-weight line to slope more positively or more negatively.

Of great importance to feeder buyers is the influence of breed, grade, sex, and age characteristics on the breakeven price-weight line. This essentially involves estimating differences across characteristics in fed prices $P_t(W_t,D)$ and feed efficiency functions $f(w_r,D)$. Inspection of (2) reveals that animals promising inferior fed prices P_t or poorer feed conversion f at a given weight receive lower breakeven prices at this weight. By inspection of (3) these animals, as well as those that lose feed efficiency relatively more slowly with increasing weight, decline in breakeven value more slowly, or rise in value more quickly, as weight increases. The magnitude of the latter slope differential is not affected by overall fed price levels as long as the fed cattle price spread remains invariant across sex, breed, grade, or age. But the slope differential is responsive to overall feed price changes. Allowing dD to indicate a comparison of two animals differing by some discrete characteristic, $f_d(w_r)$ the difference in their feed efficiency at a certain animal weight, and $f_{d,wr}(w_r)$ the difference in their rate of feed efficiency loss under weight gain,

(6) $d[d(dp_r/dw_r)/dD]/dr_d = [W_t/w_r^2]f_d(w_r) + [1-W_t/w_r]f_{d,wr}(w_r).$

In those cases where less feed efficient cattle also lose efficiency less rapidly under weight gain, both r.h.s. terms in (6) are positive; as a result rising feed prices would enlarge the difference in price-weight slopes between more and less efficient feeder cattle.

A similar analysis of breakeven price-weight relationships was conducted for a stocker operator offering feeder cattle for sale. It is not reported here out of space considerations. Briefly, a stocker profit function was developed in which breakeven sale price is a function of calf weaning weight, calf purchase price, sale weight, grazing efficiency and nonfeed cost functions, and per head costs. Stocker operators' breakeven price-weight gradients were hypothesized to algebraically increase as pasture value rises.

Theoretical Evaluation

In the feedlot buyer analysis outlined above, only function (4) has unequivocal sign; the remainder require an understanding of the feed conversion function f; daily basis nonfeed cost function g; per head basis nonfeed costs HC_f; slaughter weight W_t; and in some cases expectations of fed price P_t, daily gain ADG, and feed prices r_d. These parameters are here developed for the October, 1977 feeder cattle market and for the sex characteristic, as shown in Table 1.[2/]

Table 1. Parameters Utilized in Evaluation of Theoretical Feeder Cattle Pricing Model, Feedlot Buyer, 1977

Term	Unit	Symbol	Parameter Steers	Heifers
Feed Efficiency	Mcal ME/cwt gain	$f(w_r,D)$	$726.07+46.47w_r$	$703.94+55.58w_r$
Daily Basis Nonfeed Cost	$/day	$g(w_r,D)$	$.184 +.0067w_r$	$.147 +.0067w_r$
Head Basis Nonfeed Cost	$	H_f	26.10	24.70
Slaughter Weight	cwt	W_t	10.5 (low choice)	8.4 (low choice)
Average Daily Gain	cwt/day	ADG	.024	.020
Expected Fed Price	$/cwt	P_t	40.92	39.10
Feed Price[a/]	$/Mcal ME	r_d	.02138	.02138

[a/] Assumes the following: Corn silage (NRC #3-08-153, 40% DM, 1.1476 Mcal ME/lb DM) at $15.62/ton; Corn (NRC #4-02-931, 56 lbs/bushel, 89% DM, 1.492 Mcal ME/lb DM) at $1.81/bushel; Soybean meal (NRC #5-04-600, 90% DM, 1.393 Mcal ME/lb DM) at $139.67/ton.

Table 2. Evaluation of Theoretical Feeder Cattle Pricing Model, Feedlot Buyer, 1977

Function / Function No.	Purchase Weight	Breakeven Price[a/] (2)	Price-Weight Gradient[b/] (3)	Impact of Fed Cattle Price on P-W Gradient[c/] (4)	Impact of Feed Price on P-W Gradient[d/] (5)
Steers	5.00	47.69	-4.98	-.420	.351
	6.00	43.76	-3.07	-.292	.258
	7.00	41.31	-1.91	-.214	.202
	8.00	39.79	-1.17	-.164	.166
	9.00	38.90	- .65	-.129	.141
	10.00	38.44	- .29	-.105	.123
Heifers	4.00	44.22	-5.55	-.525	.425
	5.00	40.09	-3.00	-.336	.292
	6.00	37.84	-1.62	-.233	.220
	7.00	36.68	- .78	-.171	.176
	8.00	36.18	- .24	-.131	.148

[a/] Dollars/cwt.
[b/] Dollars/cwt price change caused by a 100 lb weight increase.
[c/] Increase in the price-weight gradient, in dollars/cwt per 100 lb. weight increase, caused by a one dollar/cwt increase in the fed cattle price (P_t).
[d/] Increase in the price-weight gradient, in dollars/cwt per 100 lb weight increase, caused by a 1/10 cent/Mcal ME increase in feed price r_d.

Values in Table 1 are substituted into functions (2)-(6). These functions are then evaluated at alternative weight levels w_r as shown in Table 2. Separate evaluations are listed for steers and heifers. Columns (2) and (3) of Table 2 reveal that price-weight gradients for steers and heifers are everywhere negative. Hence the first, third, and fifth r.h.s. terms in (3), representing diminishing sale revenue expectation per cwt purchased feeder, and constant rates of increase in feed and daily nonfeed costs per cwt gain, outweigh the second, fourth, and sixth terms, representing diminishing total feed, total daily nonfeed, and total per head costs per cwt purchased feeder.[3/]

Function (4) does unequivocally predict that rising fed cattle prices, in addition to boosting breakeven feeder purchase prices at all weights, also amplify negative (or reduce positive) price-weight slopes. In Table 2, for example, a one dollar/cwt increase in the fed cattle price algebraically diminishes a 7 cwt steer's price-weight gradient by 21¢/cwt/cwt; this impact is smaller at higher feeder weights. The indeterminacy of sign noted in the discussion of function (5) is clearly resolved for the parameter set employed here; rising feed prices not only diminish breakeven feeder purchase prices, but decrease the rate at which prices fall when weights rise. At the 5 cwt level, a 1/10 cent per Mcal ME price rise diminishes the rate of heifer price decline by 29¢/cwt per cwt. Again, this impact decreases with feeder weight.[4/]

Evaluation of function (6) according to the sex characteristic is accomplished by subtracting steer values from heifer values, weight for weight, in column (5). Beginning with 5 cwt animals, the differences are -.059, -.038, -.026, and -.018. Examination of the feed efficiency functions in Table 1 indicates that, weight for weight, heifers lose feed efficiency more quickly than do steers. Thus the second r.h.s. term in function (6) is negative and, by evidence of the negative values quoted above, greater in absolute value than the positive first r.h.s. term. It follows that under the parameters employed, feedlots seek to reduce the difference between steer and heifer price-weight gradients as feed prices rise. However, differences between the prices themselves are expected to increase under these conditions.

Evaluations of fed cattle price and feed price impacts on feeder price-weight gradients do not vary with the price levels themselves. The impacts respond only to changes in feed efficiency or nonfeed cost elements, or to changes in slaughter weights (eqs. 4,5). Since, however, theoretical price-weight gradients (3) do depend greatly on price expectations, identical simulations as in columns (2), (3), Table 2, were performed for the years 1968 through 1976. Feedlot buyers' breakeven price-weight slopes for both steers and heifers were predominantly negative in seven of these nine years; stocker sellers' price-weight slopes were eight times negative for steers and four times predominantly negative for heifers. All positive slopes occurredduring the period 1974-1976, when fat cattle/feed price ratios were low. In most cases prices decreased less rapidly, or increased more rapidly, as weight increased.

Empirical Analysis

Theoretical evaluations such as the above not only provide pricing guidance to individual firm operators, but also a source of hypotheses for statistical evaluation of feeder cattle markets. In long run, perfectly competitive equilibrium buyer and seller breakeven price lines for a specific feeder type, and at a given time and place, are identical to one another and to market prices. Although due in part to the beef price-inventory cycle this equilibrium is never achieved, theoretically hypothesized signs should predominate if a sufficiently long time frame is observed. In order to provide statistical tests of the relationships developed above, 20 years of Virginia state-graded feeder cattle transaction data were stratified by year, sex, and season, and sale prices regressed against animal and market characteristics. The former characteristics included weight, breed, grade, and age; the latter included salesize, lot-size, auction saleorder, market location, and day. Coefficients (dp_r/dw_r) of linear weight variables were then related to current Omaha 900-1100 lb. choice slaughter steer prices (P_t), current Chicago No. 2 yellow corn prices (r_c), the Palmer index of northern Virginia soil moisture conditions (PI), annual rates of change in Virginia January 1 all cattle inventories (ΔINV), and residual sex and season factors.[5/],[6/]

Sex interaction terms with the first four variables provided significance tests for differences in heifer and steer responses. Hypotheses that there were no differences in these responses were not rejected, and results shown in Table 3 allow only intercept shifts. There was no significant trend in the slope residuals and a time variable was also removed.

The coefficient of P_t in Table 3 indicates that a one dollar increase in the fed cattle price, in addition to increasing feeder prices at all weights, also caused feeder prices to increase more quickly as initial weight declined. Specifically, the price-weight line steepened 4.8 cents/cwt for every cwt reduction in initial weight (Figure 1). A dollar per bushel rise in the corn price r_c, in addition to decreasing feeder prices at all weights, caused the feeder price to increase 88.6 cents/cwt less quickly for every cwt reduction in initial weight (Figure 2). An increase of 1.0 in the Palmer soil moisture index, and a 1000 head increase in the annual rate of cattle accumulation in Virginia, increased these rates of price advance by 7.9 cents and .8 cents respectively. Even after accounting

Table 3. Determinants of Feeder Cattle Linear Price-Weight Gradients, Virginia State Graded Auction Markets, 1958-77[a]

Explanatory Variable	P_t	r_c	PI	ΔINV	SEX	SEASON	INTERCEPT
Coefficient	- .0483	.8862	- .0793	- .0083	.8024	.2489	-1.2653
t-value	- 3.59	6.15	-2.56	-7.60	7.51	2.32	-4.27
Variable unit	$/cwt	$/bu	index -5 dry to +5 wet	1000 head	index steer=0 heifer=1	index spring=0 fall=1	$/cwt/cwt
Variable mean value	31.40	1.53	- .056	7.325	.5	.5	
Hypothesized sign	Negative	Positive	Negative	Negative	Positive	Not Discussed	

[a] Dependent variable mean: -1.0178 (in $/cwt/cwt); R^2=.716; degrees of freedom=73. Steer weight ranged from 350-1200 lbs and averaged approximately 620 lbs. Heifer weights ranged from 300-1000 lbs and averaged approximately 470 lbs. Due to the sex cross-section component, a Durbin-Watson test is not valid here. However D-W values calculated in sex and season stratified models remained in the range 1.49-2.03, insufficient evidence to indicate serial correlation.

Figure 1. Impact of a $1/cwt rise in fed steer price on the feeder cattle price-weight relationship, Virginia, 1958-77 (linear approximation).[a]

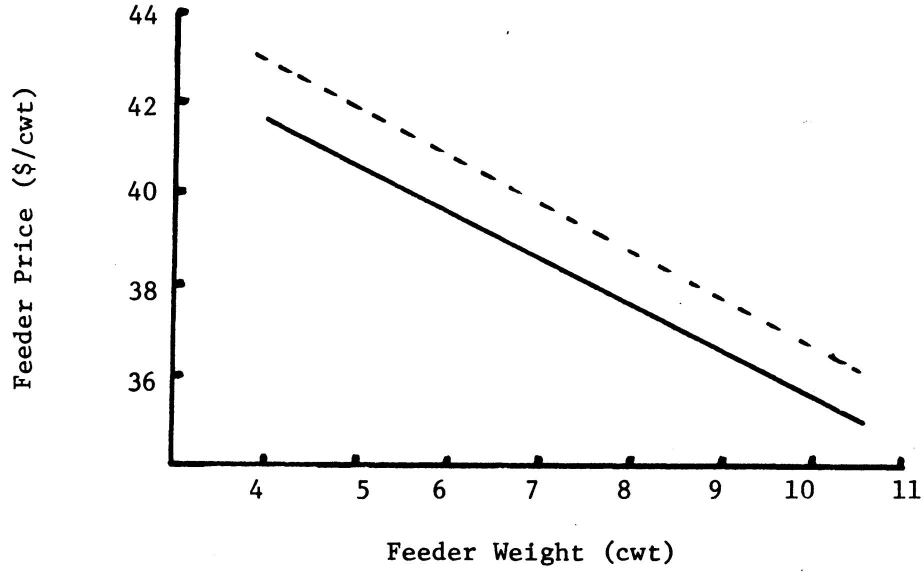
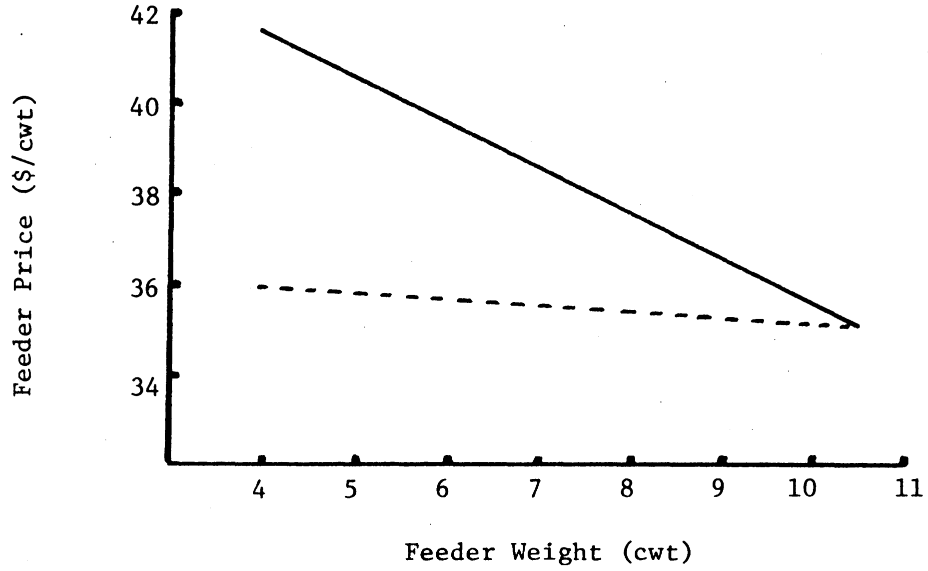


Figure 2. Impact of a $1/bushel rise in corn price on the feeder cattle price-weight relationship, Virginia, 1958-77 (linear approximation).[a]



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[a] Dotted lines indicate slopes subsequent to fed steer and corn price changes. Solid line intercepts correspond to 400 lb. choice Hereford steer prices, Virginia, Fall, 1977. Fed cattle prices differ from "1050 lb feeder" prices by a marketing charge only.

for these factors, heifer price-weight slopes are much flatter than those for steers. The average for fall heifers is, at mean explanatory variable levels, a 43¢/cwt rise per 100 lb weight reduction; for fall steers it is a $1.23 rise.

It is instructive to compare these statistical coefficients with those generated in the theoretical analysis, as reported in Table 2. At a typical steer weight of 600 lbs and heifer weight of 500 lbs, the feedlot buyer model specifies fed cattle price impacts 7 or 8 times larger, and corn price impacts 3 times larger, than those evidenced in the statistical results.[7/] Hay price was insignificant when substituted for PI as a proxy for stocker pasture value. It is reasonable that fed cattle and corn price impacts in the theoretical analysis should be greater than in the statistical analysis. The former represent behavior of buyers' zero-profit reservation prices, and the latter, behavior of market prices. Seller reservation prices are not expected to respond to corn and fed cattle prices, so that feeder market prices may respond to corn and fed cattle prices less than buyers would have wished. Similarly, except for the occasional use of hay in cattle feeding, buyer reservation prices do not respond to hay prices, with the result that feeder market prices may respond to hay prices less than sellers would have wished.

Particularly notable is the negligible difference between sexes in the determinants of market price-weight gradients. Additional statistical analysis did reveal significant differences in these impacts across breeds and grades. Further work could profitably explore price-weight line non-linearity, interactions of discrete characteristics, and alternative fed cattle and feed price expectation models. The result may be a more complete understanding of the feeder cattle pricing mechanism.

Footnotes

[1]Changes in the per unit dry matter price of a feed constituent may not be linearly related to r_d, in \$/Mcal ME, since the former often affect ration composition, and hence the ratio of total feed dry matter to ME.

[2]Estimates of feed efficiency function f, corresponding to "good" quality steers and heifers, are derived from National Research Council, pp. 22-25. Utilizing ADG and W_t quantities listed in Table 1, ME/day values associated with alternative animal weights were first expressed on a per lb. daily gain basis, then converted to represent, for the alternative feeder purchase weights, average feed efficiency achievable during feeding. Daily basis nonfeed feeder cost function g (machinery, veterinary, death loss, depreciation, interest), and per head basis costs HC_r (hauling and marketing) are adapted from Crickenberger and Black, pp. 57-71, as inflated to 1977 dollars. The feed ration employed consists of 53% corn silage, 44% cracked corn, and 3% soybean meal, ME basis (Wise, NRC). Feed and fed cattle price expectations are represented by August-October, 1977 price averages (USDA).

[3]The cost side of this statement may be re-expressed as follows: As feeder animal purchase weight rises, total feedlot costs per unit weight purchased feeder decrease. However the rate of this decrease is diminished in that feed and daily nonfeed cost efficiency decline as purchase weight rises. The first factor influences the breakeven price upward, the second downward.

[4]If corn were the entire ration, a .10¢/Mcal ME price rise would result from a 9.4¢/bu increase in the corn price.

5/ The Palmer Index (PI) of drought conditions (Smith) varies directly with soil moisture, hence should usually vary inversely with pasture value.

6/ ΔINV is $INV_t - INV_{t-1}$ where t refers to the January 1 inventory following the time period of regression. This variable is designed to account for inventory disequilibria. It is expected that rising inventories are associated with steeper price-weight lines since light calf prices are bid up relative to heavy stockers in anticipation of higher feeder cattle prices.

7/ An increase of .10¢/Mcal ME in the corn price would increase the price-weight gradient by .0833. (This is .8862 x .094; see footnote 4.)

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