A U. S. REGIONAL MODEL OF FEEDER STEER-HEIFER PRICE DIFFERENTIALS.

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U.S. feeder cattle markets discriminate among a wide variety of animal characteristics such as weight, sex, breed, grade, and age. In recent years, concern has been expressed that price premiums paid for steers over heifers no longer reflect estimated differences in their feedlot performance or carcass value [2,8]. Another question is whether observed regional differences in steer-heifer price differentials are justified. The sources of feeder price differentials by sex are investigated and variations in these differentials across time and space dimensions are analyzed. The results provide preliminary evidence on the efficiency with which feeder markets establish price spreads.

THE MARKET MODEL

As a point of departure for the analysis, simplified demand and supply relations are specified for feeder steers and heifers, ignoring time lags.

$$\text{(1)}\quad \begin{aligned} Qfs^s &= f_1(pfs, BCs, ICOW, Epfs)\\ Qfh^s &= f_2(pfh, BCh, ICOW, Epfh)\end{aligned}$$

$$\text{(2)}\quad \begin{aligned} Qfs^d &= f_3(pfs, PSs, FCs, FIs)\\ Qfh^d &= f_4(pfh, PSh, FCh, FIh)\end{aligned}$$

where

Qfs^s, Qfh^s, Qfs^d, Qfh^d = supplied quantities of steers and heifers, and demanded quantities of steers and heifers, respectively
pfs, pfh = per cwt feeder prices (steers denoted by s, heifers by h)
BCs, BCh = backgrounding costs
ICOW = brood cow inventory
Epfs, Epfh = expected future per cwt feeder prices
PSs, PSh = per cwt slaughter prices
FCs, FCh = feeding costs
FIs, FIh = feedlot inventories.

Discrepancies in quantities of feeder steers and heifers supplied or demanded are then found by differencing equation sets 1 and 2.

$$\text{(3)}\quad \begin{aligned} Qfs^s - Qfh^s &= f_5(pfs-pfh, BCs-BCh, Epfs-Epfh)\\ Qfs^d - Qfh^d &= f_6(pfs-pfh, PSs-PSh, FCs-FCh, FIs-FIh)\end{aligned}$$

Feeder markets are in equilibrium only when these discrepancies have been equated; that is, $Qfs^s - Qfh^s = Qfs^d - Qfh^d$. The objective is analysis of the endogenous feeder price differential (pfs−pfh), and it is convenient to use this market clearing identity to derive the reduced form

$$\text{(4)}\quad pfs-pfh = f_7(BCs-BCh, Epfs-Epfh, PSs-PSh, FCs-FCh, FIs-FIh).$$

Expression 4 states that the feeder sex price differential is determined by sex-based diffeences in backgrounding costs, expected future feeder prices, slaughter prices, feeding costs, and current feedlot inventories.

VARIABLE ANALYSIS: THEORETICAL

The aggregate market price relationship represented by equation 4 has its source in profit-motivated decisions of individual cow-calf, stocker, and feedlot operators. Models of pricing decisions made by these operators serve to explain the presence of several of the explanatory variables in equation 4, and also help formulate expectations of the signs and magnitudes of their effects on the steer-heifer price differential. Consider, for example, the per-head profit function π faced by a feedlot operator:

$$\text{(5)}\quad \pi = P(W,D)W - r[W-w]f(w,D/W) - [W-w]g(w,D/W) - h(D) - pw$$

where

W,w = sale weight of slaughter and purchase weight of feeder cattle, respectively, in cwt

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D = discrete breed, age, grade, and sex description
$P(W,D)$ = slaughter cattle price, in \$/cwt
p = feeder cattle price, in \$/cwt
r = feed ration price, in \$/Mcal metabolizable energy
$f(w,D/W)$ = feed efficiency, in Mcal/cwt gain
$g(w,D/W)$ = variable nonfeed costs at feedlot, in \$/cwt gain
$h(D)$ = per-head nonfeed costs as feedlot, in \$.

Terms on the right side of equation 5 respectively represent slaughter steer or heifer sale revenue, feed cost, nonfeed cost determined on a weight basis, nonfeed cost determined on a head basis, and feeder animal cost.[1] Variables in parentheses are function arguments; for example, in the revenue term, slaughter cattle price P is a function of slaughter weight W and a set of discrete animal descriptions D, including sex and grade. Feed efficiency function f(w,D/W) represents the average feed/gain ratio achieved when a feeder of description D is placed on feed at weight w and sold at preassigned slaughter weight W.[2]

The feedlot operator may locate feeder prices p consistent with a target profit K by equating 5 with K and solving for p.

$$(6)\quad p = P(W,D)W/w - r[W/w-1]f(w,D/W) - [W/w-1]g(w,D/W) - h(D)/w - K/w.$$

A variant of equation 6 has been used to analyze price-weight relationships in feeder cattle markets [1]. Here equation 6 is differentiated with respect to the sex characteristic C ($C \varepsilon D$) instead.

$$(7)\quad p_c = pfs-pfh = P_c(W,D)W/w - r[W/w-1]f_c(w,D/W)/w - [W/w-1]g_c(w,D/W)/w - h_c(D)/w$$

C is O if the feeder is a heifer and 1 if a steer. Derivatives with respect to C, shown by c subscripts, indicate differentials between steers and heifers, so that p_c is equivalent to feeder price differential (pfs−pfh), $P_c[W,D]$ is equivalent to slaughter cattle price differential (PSs−PSh), and the last three terms in equation 7 are together equivalent to feedlot cost differential (FCs−FCh) in equation 4.

Equation 7 represents the price differential feedlots must maintain between feeder steers and heifers, given fixed levels of all other parameters, to achieve target profit K. Under normal conditions the expression is positive, meaning higher per cwt prices for feeder steers, because steers promise higher per cwt slaughter prices [$P_c(W,D)$ is positive] and better feeding efficiency [$f_c(w,D/W)$ is negative], whereas nonfeed cost differentials $g_c(w,D/W)$, $h_c(D)$ are small. Expected impacts of changes in slaughter cattle price differential $P_c(W,D)$ and in per-cwt-gain feed cost differential $rf_c(w,D/W)$ on the steer-heifer feeder price spread are determined by differentiating equation 7 with respect to $P_c(W,D)$ and feed price r.

$$(8)\quad dp_c/dP_c = W/w > 1$$

$$(9)\quad dp_c/dr = -[W/w-1]f_c(w,D/W)/w > 0$$

Equations 8 and 9 indicate that increasing price premiums for slaughter steers over slaughter heifers, or increasing feed prices, lead to increasing price premiums bid for feeder steers over feeder heifers. Parallel development of the per-head profit function for a cow-calf or stocker operator can be used to indicate that increases in hay prices or pasture value, because they augment steer-heifer backgrounding cost difference BCs−BCh, lead to increased differentials between asking prices of feeder steers and heifers.

Firm profit model 5 is not helpful for analyzing the impacts of expected future feeder price spreads (Epfs−Epfh) or steer-heifer inventory differences (FIs−FIh) in market model 4. Therefore a more *ad hoc* approach to these variables is adopted. Although (Epfs−Epfh) is generated by the differencing process in equation 3, it is not likely that cow-calf or stocker operators plan sales of steers and heifers on the basis of differences in their expected future prices. They are more likely to be interested in current overall rates of change in feeder prices and to use these to predict future feeder prices. Predictions of short- or long-term feeder price increases motivate farmers to hold back both steers and heifers in anticipation of capital gains. In addition, predictions of long-term price increases encourage farmers to increase the rate at which they retain heifers for breeding purposes. Together, these reactions serve to increase current prices for both feeder steers and heifers, so that the net impact of a change in the rate of change of feeder prices on the current steer-heifer price differential is difficult to anticipate *a priori*. If, for example, price advances were to stimulate mild expansion in cow herds but strong near-term demand for

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[1] Nonfeed costs that vary on the basis of weight gain in fact represent the product of average daily gain and nonfeed cost per day. This refinement does not illuminate the present analysis and is ignored.

[2] It is most meaningful for this analysis to stipulate that all animals represented in equation 5 achieve an identical slaughter grade. If, for example, Low Choice is used, equivalent slaughter weights for heifers and steers are 850 and 1050 lbs., respectively. Price and cost functions for steers can be shifted 200 lbs. to the left to express them on a heifer-weight-equivalent basis.

steer grazers, these advances would be expected to increase steer-heifer price spreads. Rapid herd expansion would tend to diminish these spreads.

Buyers' inventories are normally hypothesized to affect purchase prices negatively because inventories serve as a substitute for new purchases. Thus, inventory difference (FIs−FIh) in equation 4 should negatively influence the steer-heifer price differential. In contrast, differences in the numbers of steers and heifers on feed, especially if long-term, may reflect certain feedlots' or regions' predisposition to specialize in one sex or the other. If so, one should expect feedlots handling proportionately more steers, say, to offer a price premium for steers. A ratio of steers to total head on feed would represent such predisposition better than would an inventory difference because the latter is also responsive to differences in total feedlot inventories.

VARIABLE ANALYSIS: EMPIRICAL

Empirical analysis of the hypothesized relations was approached by specifying six calf stocking regions and five cattle feeding regions in the United States. Observations on slaughter cattle price differentials, cattle on feed, and feed prices were drawn from feeding regions and corresponded to feeder cattle price differentials, feeder cattle price changes, and hay prices in the stocking region from which the feeders were assumed to originate.[3] Stocking regions include the Southern Mid-Atlantic, Southeast, Southern Plains, Far West, Rocky Mountains, and Western Corn Belt. Feeding regions include the latter four plus the Eastern Corn Belt. Each region is represented by a market point and state.[4] The following statistical model was used.

$$(10)\quad (pfs-pfh)_{it} = a + b_1PHAY_{it} + b_2PE_{it} + b_3(PSs-PSh)_{i't} + b_4CRN_{i't} + b_5PSOF_{i't} + c_1R_{i=se} + c_2R_{i=sp} + c_3R_{i=fw} + c_4R_{i=rm} + c_5R_{i=wcb} + e_{it}$$

where

$(pfs-pfh)_{it}$ = price differential between fall Choice 400-500 lb steers and heifers, in \$/cwt

$PHAY_{it}$ = annual average grower price of all hay, in \$/ton

PE_{it} = fall Choice 400-500 lb feeder steer price minus average of these prices for the preceeding 3 years, in \$/cwt

$(PSs-PSh)_{i't}$ = price differential between fall Choice 11-1300 lb steers and fall Choice 900-1100 lb heifers, in \$/cwt

$CRN_{i't}$ = annual average grower price for all corn, in \$/bushel

$PSOF_{i't}$ = number of steers on feed divided by the number of steers and heifers on feed, annual average of quarterly data

R_i = zero-one variables by stocking region (se=Southeast, sp = Southern Plains, fw = Far West, rm = Rocky Mountains, wcb = Western Corn Belt)

t subscripts refer to years, i to stocking regions, and i' to corresponding feeding regions.

Feeder and slaughter cattle prices were obtained by direct communication with the Agricultural Marketing Service, USDA. Hay and corn prices were obtained from [6] and numbers of steers and heifers on feed from [7]. Data were drawn from the period 1964-1976. Because, for some stocking regions, high serial correlation coefficients were observed in OLS residuals and because it did not seem appropriate to assume constant residual variances among stocking regions, the Parks Generalized Least Squares estimator was used to derive coefficient estimates [5, pp. 512-514].

The estimation strategy was first to regress feeder price differential $(pfs-pfh)_{it}$ against only the stocking region zero-one variables to test for significant regional differences in this differential. The five supply and demand variables were then included as regressors to test whether they explain some of the observed regional differences in the price differentials. Results of the analysis are given in Table 1. Equation A in Table 1 indicates that mean feeder steer-heifer price spreads in the Southern Mid-Atlantic base region are higher than those in any other stocking region. Subsequent comparison of steer prices by region, then heifer prices by region, suggested this phenomenon is due to higher discounts on heifers rather than higher premiums on steers. Successive identification of each stocking region as base region revealed that average feeder sex price spreads in the Southeast, Rocky Mountains, and Corn Belt do not significantly differ at the 5 percent

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[3] The Southern Mid-Atlantic was assumed to send 65 percent of its feeders to Pennsylvania and 35 percent to Ohio. The Southeast shipped 50 percent to Texas and 50 percent to Oklahoma. The remaining four stocking regions retained all cattle for feeding within-region. These very approximate estimates are drawn from [3], [4], and state agricultural experiment station personnel.

[4] Representative market points and states are, in the order of regions listed in the text: Virginia statewide; Thomasville, GA; Oklahoma City, OK; San Francisco and Visalia, CA; Greely, CO; and Springfield, IL. Lancaster, PA represented the Eastern Corn Belt. Regional Boundaries are necessarily loosely drawn around these markets.

level (they averaged \$4.32). Mean price spreads in the Far West and Southern Plains (\$5.80) also do not differ significantly, but are significantly above those in the former group and below those in the Southern Mid-Atlantic (\$7.58).

All variables for which the stocker and feedlot profit models provided theoretical basis, $PHAY_{it}$, $(PSs-PSh)_{i't}$, and $CRN_{i't}$, have correct signs and are highly significant. The impact of slaughter price differentials on feeder price differentials is rather minor; at mean sample values, a 10 percent rise in the former results in only a 0.7 percent rise in the latter. In contrast, hay and corn prices have fairly strong influence on feeder sex price spreads. A one dollar per bushel increase in the price of corn boosts steer-heifer price differences one dollar; at sample means this implies a 3.2 percent rise in the feeder price spread for every 10 percent rise in the corn price.

Both variables for which sign expectations were developed on a more *ad hoc* basis also have positive and significant coefficients. Preferences of feeding regions for feeding one sex rather than the other, as reflected in proportions of steers on feed ($PSOF_{i't}$), do appear to affect strongly the sex price differences observed in the regions from which the cattle are procured. The net effect of an algebraic increase in the rate of change in steer prices (PE_{it}) is to increase steer prices more than heifer prices. This in turn implies that, in the average year, increased feeder price optimism serves to stimulate demand for steers for farm grazing more than it stimulates demand for heifers for stocking or breeding purposes. Such a result is not surprising in view of farmers' strong preference for stocking steers rather than heifers, the rather gradual annual rate of expansion in cow herds reported during the 1964-1972 period, and the decision of many feeding funds in the early 1970s to concentrate on steer feeding.[5]

Comparison of stocking region intercept shifters R_i in equations A and B shows that inclusion of the hypothesized demand and supply variables explains: (1) the entire mean difference between Southern Mid-Atlantic feeder steer-heifer price differentials and those in the Southeast and Southern Plains, (2) about 60 percent of the mean difference between the Southern Mid-Atlantic differential and those in the Rocky Mountains and Western Corn Belt, and (3) none of the difference between the Southern Mid-Atlantic and Far West. Hence the model explains roughly two-thirds of the regional differences in feeder sex price differentials. Because removing the regional dummies from equation B only decreased the R^2 to .72, one can infer that the demand and supply variables are much more successful in explaining temporal than contemporaneous regional differences in the steer-heifer price spread. Corn prices ($CRN_{i't}$) and rates of feeder steer price change (PE_{it}) do not significantly differ among regions and hence explain only temporal changes in the dependent variable. Most of the regional variation in feeder steer-heifer price differentials is explained by differences among regions in slaughter steer-heifer price spreads and in the proportion of steers to total cattle on feed.[6]

TABLE 1. IMPACTS OF SUPPLY, DEMAND, AND REGIONAL INTERCEPT SHIFTERS ON FALL FEEDER STEER-HEIFER PRICE DIFFERENTIALS, U.S. CHOICE GRADE 400-500 LBS, 1964-76[a]

Explanatory Variable	Intercept	$PHAY_{it}$	PE_{it}	$(PSs-PSh)_{i't}$	$CRN_{i't}$	$PSOF_{i't}$	$R_{i=se}$	$R_{i=sp}$	$R_{i=fw}$	$R_{i=rm}$	$R_{i=wcb}$
Equation A[b]	7.581 (9.189)						-2.978 (-3.909)	-1.613 (-3.264)	-1.946 (-3.913)	-3.167 (-4.186)	-3.617 (-7.435)
Equation B[c]	-2.324 (-1.691)	.091 (6.798)	.140 (12.915)	.262 (2.688)	1.000 (4.063)	4.449 (3.265)	-.821 (-1.202)	.762 (1.236)	-2.204 (-5.139)	-1.106 (-1.643)	-1.422 (-2.936)
Elasticity at the Centroid		.572	.030	.074	.321	.575					
Mean Value (and Standard Deviation)		\$34.49/ton (\$11.59/ton)	\$1.17/cwt (\$9.81/cwt)	\$1.55/cwt (\$0.99/cwt)	\$1.76/bu (\$0.69/bu)	71% (16%)					
Hypothesized Sign		Positive		Positive	Positive	Positive					

[a] Coefficients are derived using the Parks Generalized Least Squares estimator. R-squares listed are uncorrected and are derived from corresponding OLS fits [5, pp. 512-514]. Parenthesized numbers are t-values.

[b] Equation A: base region = Southern Mid-Atlantic, $R^2 = .280$, df = 72.

[c] Equation B: base region = Southern Mid-Atlantic, $R^2 = .862$, df = 67, dependent variable mean = \$5.49.

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[5] Whereas price differences between feeder steers and heifers fluctuate widely across years, the ratio of feeder steer to feeder heifer prices does not. This ratio averaged approximately 1.2 during the 1964-1976 sample period. The null hypothesis that the rate of steer price change (PE_{it}) has no effect on the ratio was not rejected at the 5 percent probability level, suggesting that increases in predicted steer prices cause *proportionately* equal increases in current steer and heifer prices.

[6] The Rocky Mountains, Southern Plains, and Western Corn Belt feed much lower proportions of steers than do the Far West and Eastern Corn Belt.

If one were certain that all demand and supply variables in this study were specified correctly and that no factors affecting steer-heifer price spreads have been excluded, one would conclude from the significant regional intercept shifters in equation B of Table 1 that there is considerable pricing inefficiency in feeder cattle markets. Unfortunately, additional factors for which data are not readily available probably are important in steer and heifer pricing—regional differences in heifer pregnancy rates, relative steer-heifer frame sizes (due, for example, to breed), relative performance of steers and heifers on feed, preference of credit sources for steer or hedged feeding, and errors in the assumed feeder shipment matrix. It would be surprising if these excluded factors explained the entire residual regional variation in feeder sex price spreads represented by the significant zero-one variables in equation B. On this basis, one would suspect some imperfections, such as uneven grading procedures or imperfect access to market information, in U.S. feeder cattle markets. The exact importance of the imperfections is not known, and until additional information becomes available on feedlot performance by sex and region of origin, one would not confidently assert that these imperfections are great.

The statistical results do provide information about the relative importance of buyers and sellers in the feeder price discovery process. Some of this information contains ambiguity resulting from multicollinearity among explanatory variables. For example, the model's coefficient estimates suggest that hay prices, which principally represent backgrounding costs, have as strong an impact on sex price differentials as any variable representing feedlot demand. But it is likely that the demand high positive correlation between hay and corn prices (.805) serves to confound the impact of each of these variables, and may result in a higher estimated hay price effect than is warranted in reality. Another statistic appears less ambiguous: the marginal influence of slaughter cattle on feeder cattle price spreads shown in Table 1 is considerably below one, and hence less than that predicted by the feedlot demand relation (equation 8). Feedlot operators correctly influence feeder price spreads in response to changes in feedlot profitability factors, but not to the extent profit-motivated operators would have wished.

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