Steer and Heifer Price Differences in the Live Cattle and Carcass Markets

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A dynamic model is used to estimate quarterly price differences between steers and heifers in the feeder, slaughter, and carcass markets. For cattle within the same weight and grade range, their price differences are hypothesized to be influenced by seasonal, economic, and stochastic factors. The effect of stochastic factors is large in the carcass and fed cattle markets, partly reflecting time changes in evaluation of steer and heifer quality in the live cattle and dressed meat trades. Stochastic factors are less prevalent at the feeder level, although risk of placing pregnant heifers in feedlots and weather are important. Steer and heifer inventories, slaughter prices, cost of gain, and margins explained most of the variation in feeder steer and heifer price differences.

Price premiums and discounts between steers and heifers typically vary over time and space. For example, periodically, young heifers may sell at a smaller price discount during the rapid growth stage of the cattle cycle compared to the deceleration stage since they are in greater demand for herd replacement (Hasbargen and Egertson). The opposite may run true during the herd liquidation period of the cycle. Also, across regions of the U.S., some feedlots (or packers feeding cattle) demand relatively more heifers since the number of days on feed is shorter; that is, heifers mature at lighter finishing weights than steers. However, some large commercial cattle feeders may demand relatively more steers because the cost is higher if they must handle large numbers of non-open heifers (BEEF Magazine).

This paper analyzes price differences between steer and heifer cattle at the feeder, slaughter, and wholesale levels of the market (the latter restricted to carcass prices). These price differences are restricted to cattle within the same weight range and grade categories. Some producers feel that the magnitude of sex price differences for cattle of the same weight and grade are not justifiable and that there is a bias against heifers. An example is heifers that are placed in feedlots at a \$10–\$12 per cwt. discount to steers, but when finished as fed heifers, they sell at only a \$2–\$3 per cwt. discount to fed steers. Thus, if the magnitude of this price spread is unwarranted (too large), returns from selling feeder steers and heifers (to feedlots) are unjustifiably low.

To test sex price behavior, a quarterly econometric model was formulated, directly estimating steer and heifer prices and their price differences based upon seasonal and economic variables. Price behavior is hypothesized to be a dynamic adjustment process, attributed to biological factors and economic expectations in the market. For example, if feedlot cost of grain increased, feedlot operators' change in demand for steers versus heifers (i.e., adjustments in their price differences) would take into account expected biological performance, feed efficiency,

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and the perception of how permanent the increase in the cost of gain might be.

Historical data show that, at all three market levels, prices of steers are consistently higher than prices of heifers within the same weight and grade categories. The greatest difference occurs at the feeder level, with considerably smaller price spreads at the slaughter and carcass levels. Also, the largest variations in steer and heifer price differences occur in the feeder market. At the feeder level, Boggs and Merkel attribute these price differences to physiological and growth factors in steers versus heifers and to the costs of handling pregnant heifers in feedlots. More recently, increased usage of abortifacients has reduced the pregnancy problem. At the slaughter level, meat packers generally consider steer carcasses to be of better quality than heifer carcasses since they tend to have better marbling characteristics (Riley). Since, in addition, the average weights of heifer carcasses are less than those of steer carcasses, per unit processing costs for heifers are higher. Given these factors, there has been a relatively higher demand for steers.

Previous Work

The literature is meager regarding steer-heifer price premiums and discounts at different levels of the market. Most of the work has been done at the stocker-feeder level. Buccola and Jessee (1979) investigated feeder price differences by sex and analyzed their variations over time and space. Feeder steer and heifer price differences were a function of different backgrounding and finishing costs per pound of gain, expected future feeder price, price differences between slaughter steers and heifers, and inventories of steers and heifers. Results also showed that feeder sex price differences varied according to feeding regions, reflected in the proportion of steers to total cattle on feed and in the differences between slaughter prices of steers and heifers. Buccola (1980) showed that breakeven analysis could be used to analyze price premiums and discounts between different lots of feeder cattle. The results indicated that the variables that impact individual feeder prices also determine price differences between classes of feeder cattle. Feeder cattle price-weight slopes were estimated as a function of expected slaughter cattle prices, feed prices, soil moisture conditions, and inventory adjustments. Lambert *et al.* determined the effect of management and marketing factors on the prices of calves and yearlings of both gender. Though emphasis was on price differences across weight categories, the results also measured discounts on steer and heifer prices emanating from the traits of health, body condition, frame, and grade. The statistical results revealed that steer price-weight discounts exceeded those for heifers when these traits deviated (negatively) from normal levels for both sexes. Folwell and Rehberg utilized cross section data to estimate prices of individual lots of calves and stocker-feeders in eastern Washington. The results revealed that premiums and discounts were sensitive to sex, weight, grade, breed, lot size, and general appearance of cattle.

Model and Methodology

Our structural model tests for systematic and stochastic behavior in prices and price differences for steers and heifers via distributed lags. Distributed lags are hypothesized since, on a quarterly basis, the impacts of certain economic variables are expected to extend beyond one time period. The model also provides the necessary link between the carcass, slaughter, and feeder levels of the market. These links, as seen below, are accomplished as prices from the higher market levels feed into the lower market levels. The latter is necessary since, on a short term basis, feeder prices depend upon prices in the slaughter and dressed meat trade (Brester and Marsh; Crom; Cromarty). Thus, it is hypothesized that prices for steer and heifer carcasses and their premium-discount relationship directly impact slaughter steer and heifer price differences (USDA). The slaughter market, in turn, partly determines steer and heifer prices at the feeder level. Gender price differences at each market level are also unique in that they are characterized by certain economic variables specific to only that level. An example is feedlot cost of gain at the feeder level and the value of by-products at the slaughter level.

The following equations represent the price relations for steers and heifers at the three market levels:

$$[PSC_t, PHC_t, PSC_t - PHC_t; D, QSHC_{t-j}, QPKPY_{t-j}, BPVC_{t-j}, Y_{t-j}, MCR_{t-j}, E(DEP_{t-i}), U_{1t}] \quad (1)$$

$$[PSS_t, PSH_t, PSS_t - PSH_t; D, QFS_{t-j}, QNFS_{t-j}, PSC_{t-j}, BPVF_{t-j}, E(DEP_{t-i}), U_{2t}] \quad (2)$$

$$[PFS4\text{-}5_t, PFH4\text{-}5_t, PFS4\text{-}5_t - PFH4\text{-}5_t; D, PSS_{t-j}, QFS_{t-j}, QFH_{t-j}, MFC_{t-j}, PC_{t-j}, E(DEP_{t-i}), U_{3t}] \quad (3)$$

$$[PFS6\text{-}7_t, PFH6\text{-}7_t, PFS6\text{-}7_t - PFH6\text{-}7_t; D, PSS_{t-j}, QFS_{t-j}, QFH_{t-j}, MFC_{t-j}, PC_{t-j}, E(DEP_{t-i}), U_{4t}] \quad (4)$$

$$i \geqq j$$

Table 1 presents the definitions of the variables. All variables are stated in nominal terms, however, in the regression program the price and income variables are deflated by the Consumer Price Index (1972 = 100) and the quantity variables are deflated by population. Quarterly data from 1971 through 1982 are used, gathered from the USDA's Livestock, Meat, and Wool Statistics and Livestock and Meat Statistics reports. All variables to the left of the semicolons are the dependent variables, while all variables to the right of the semicolons are the independent variables. A total of 12 price equations are specified, eight consist of individual steer and heifer prices and four consist of their price differences. For each market level, the same set of regressors is specified in the price premium equations as in the individual price equations, since the former are determined by similar economic and technical factors (i.e., cost of gain and inventory levels).

The specification of each function is based on theoretical precepts and prior knowledge of the industry. At the carcass level (equation 1), steer and heifer prices are hypothesized to be a function of wholesale production (QSHC, QPKPY), carcass by-product value (BPVC), a retail demand factor (Y), and carcass-retail marketing cost (MCR). Beef carcass production and pork and poultry production measure the effects of direct and competitive meat supplies on price. By-products extracted from carcasses are usually sold by packers for edible and inedible purposes. Thus, changes in their values are expected to affect the value (price) of steer and heifer carcasses. Income is specified to measure changes in retail demand that filter back to the wholesale level. Thus, if consumer demand changes because of exogenous shifts in disposable income, this should have a noticeable impact on the dressed meat trade. The margin variable is included to measure the impact of changes in processing and distribution costs on carcass prices. Increases in such costs, ceteris paribus, would decrease carcass prices as retailers would decrease their offer (buying) price.

At the slaughter level (equation 2), steer and heifer prices are hypothesized to reflect changes in production (QFS and QNFS), slaughter by-product values (BPVF), and steer carcass price (PSC). The variables QFS and QNFS are numbers of fed cattle and nonfed cattle slaughtered, respectively, where the latter represents a lower quality grade of beef. Changes in the value of edible and inedible slaughter by-products are hypothesized to affect slaughter price since they usually pay for slaughter costs and profits (Doane). Finally, the inclusion of steer carcass price (PSC) is to act as a proxy for the direct effect of changes in the wholesale market on the live slaughter market. For example, since

TABLE 1. Definitions of the Variables for the Steer and Heifer Price Premium Model.

PSC =	price of Choice, yield grade #3 steer carcasses, 600–700 lbs., Omaha ($/cwt.) (endogenous).
PHC =	price of Choice, yield grade #3 heifer carcasses, 600–700 lbs., Omaha ($/cwt.) (endogenous).
PSC − PHS =	the difference between steer and heifer carcass prices ($/cwt.) (endogenous).
QSHC =	quantity of steer and heifer carcasses (billions of lbs.) (exogenous).
QPKPY =	quantity of commercial pork and young chicken supplied (billions of lbs.) (exogenous).
BPVC =	by-product value for Choice, yield grade #3 beef carcasses (cents/lb.) (exogenous).
Y =	per capita disposable personal income (dollars) (exogenous).
MCR =	beef carcass-to-retail margin (cents/lb.) (endogenous).
D =	seasonal dummy variables specific to three calendar quarters with the January through March period omitted.
$E(DEP_{t-i})$ =	the ith lag on the expected value of the dependent variable (applies to all price equations).
PSS =	price of Choice, yield grade #3 slaughter steers, 900–1,100 lbs., Iowa ($/cwt.) (endogenous).
PSH =	price of Choice, yield grade #3 slaughter heifers, 900–1,100 lbs., Iowa ($/cwt.) (endogenous).
PSS − PSH =	the difference between slaughter steer and heifer prices ($/cwt.) (endogenous).
QFS =	quantity of commercial fed steer and heifer slaughter (millions of head) (exogenous).
QNFS =	quantity of commercial cattle slaughter, nonfed steer and heifers (millions of head) (exogenous).
BPVF =	by-product value for Choice, yield grade #3 slaughter steers (cents/lb.) (exogenous).
PFS4–5 =	price of medium frame #1 steer calves, 400–500 lbs., Kansas City ($/cwt.) (endogenous).
PFH4–5 =	price of medium frame #1 heifer calves, 400–500 lbs., Kansas City ($/cwt.) (endogenous).
PFS6–7 =	price of medium frame #1 feeder steers, 600–700 lbs., Kansas City ($/cwt.) (endogenous).
PFH6–7 =	price of medium frame #1 feeder heifers, 600–700 lbs., Kansas City ($/cwt.) (endogenous).
PFS4–5 − PFH4–5 =	the difference between steer and heifer calf prices ($/cwt.) (endogenous).
PFS6–7 − PFH6–7 =	the difference between feeder steer and heifer yearling prices ($/cwt.) (endogenous).
QFS =	number of steers on feed, 13 states, millions of head (endogenous).
QFH =	number of heifers on feed, 13 states, millions of head (endogenous).
MFC =	farm-to-carcass marketing margin (cents/lb.) (endogenous).
PC =	price of #2 yellow corn, Omaha ($/bu.) (exogenous).
U =	random disturbance terms (numbered for each equation). Each is assumed to have zero mean, constant variance, and serial independence.

carcass price represents an output price to packers, an exogenous increase in carcass price would cause packers to bid higher prices for existing supplies of slaughter cattle.

Calf and yearling steer and heifer prices (equations 3 and 4) directly affect the welfare of cow-calf and yearling producers. These prices are hypothesized to be a function of steer price in the fed slaughter market (PSS), inventories of feeder steers and heifers (QFS, QFH), cost of gain in the feedlot (PC), and a marketing cost between the rancher and the packer (MFC). A priori, the effect of a change in slaughter market price would be expected to exert a strong influence on feeder prices since the former represents the output price to the cattle feeder (thus, affecting the derived demand for feeder cattle inputs). Steer and heifer inventories reflect feeder cattle supplies. It is expected that changes in the supply of one gender relative to another would change their price difference. The cost of gain, represented by the price of corn, would be expected to influence feeder steer and heifer prices because of its effect on cattle feeding margins. Coupled with the fact that feed conversion of heifers is not as efficient as that for steers, changes in feed costs would be expected to change the relative placement demands between steers and heifers. Also, feeder prices for each weight category may not respond equally to changes in feed costs because of different risks involved in raising calves and yearlings to finishing maturity. Margins were included to capture the effect of marketing costs on the derived demand for feeders. Ceteris paribus, larger marketing charges translate into reduced derived demand, hence lower feeder cattle prices.

All the equations above are treated as reduced form relations, estimated by rational distributed lags. Rational lags have been shown to have a flexible generating function which can approximate most lag forms (Jorgenson). Sims also shows that estimating unknown lag coefficients by rational lags may yield tighter approximation properties, i.e., a more precise estimate of the true lag structure, than those of other dynamic regression methods. Each equation is specified as a difference equation; however, the lagged expectations of the dependent variable are used rather than the lagged observed values. This procedure allows the systematic part of each equation to be strictly exogenous when the disturbance term is autocorrelated (Marsh). For any price equation, the application of Jorgenson's rational lag is:

$$P_t = W(L)Z_t \tag{5}$$

and

$$W(L) = \frac{\beta(L)}{\lambda(L)}, \tag{6}$$

where Z_t is a vector of independent variables; $W(L)$ is a rational generating function expressed as the ratio of two polynomials (with no characteristic roots in common); the numerator $\beta(L)$ is an mth order polynomial in the lag operator L, and the denominator $\lambda(L)$ is an nth order polynomial in the lag operator L.[1] The function $W(L)$ is constrained to all of Z_t, thus, the denominator $\lambda(L)$ is imposed across all the independent variables. This implies, for example, that if $\lambda(L)$ implied a first order difference equation, then the dependent variable would decline geometrically over time in response to a change in any independent variable (Griliches). If we arbitrarily let $m = 1$ and $n = 2$, apply the concept of nonstochastic difference equations as given in Marsh and Rucker *et al.*, and add a disturbance term, equation (5) is reduced to:

$$P_t = \beta_0 + \beta_1 Z_t + \beta_2 Z_{t-1} + \lambda_1 E(P_{t-1}) + \lambda_2 E(P_{t-2}) + u_t. \tag{7}$$

Equation (7) is a second order difference equation and the error term is an autoregressive structure of $u_t = \rho_1 u_{t-1} + \ldots + \rho_q u_{t-q} + \epsilon_t$, where ϵ_t is white noise. The lagged expectations of the dependent variable are purely predetermined, therefore the estimated parameters of the systematic portion of the equation are uncorrelated in the limit with the estimated parameters of the error structure. In models of this nature where there may be an autocorrelated error structure and/or lagged expectations of the dependent variable, nonlinearities in the parameters occur. Thus, least squares estimates of the model were obtained by a consistent maximum likelihood estimator developed from a modified marquardt nonlinear least squares algorithm. To handle potential problems of

[1] In the rational lag formulation, its application in our model was that $\beta(L)$ determined the order of lags on the independent variables and $\lambda(L)$ determined the order of lags on the dependent variables. Initially, they were set at a lag of two quarters. The error structure was initially estimated as second order autoregressive, the same order as the difference equation. However, based on asymptotic t ratios, the higher order β, λ, and ρ coefficients were truncated if not significant. Thus, in the final set, there was a variation among the equations as to the order of lags.

TABLE 2. Statistical Results of Quarterly Steer and Heifer Carcass Prices and Price Difference.

Equation	Constant	Variables[a]				
		D2	D3	D4	QSHC	QSHC − 1
PSC[c]	−11.478	−.559	−1.606	−2.004	−13.638	10.943
	(−1.630)	(−.681)	(−2.378)	(−2.394)	(−5.124)	(3.215)
PHC	−7.893	−.995	−2.257	−2.051	−14.150	10.979
	(−1.095)	(−1.189)	(−3.420)	(−2.522)	(−5.452)	(3.267)
PSC − PHC	−1.157	.150	.477	.278	.899	—
	(−.984)	(.657)	(2.095)	(1.220)	(1.653)	

[a] The asymptotic t ratios are given in parentheses below each coefficient. The critical boundary is 2.030 for a 95 percent probability level (degrees of freedom are 35).
[b] Represents the expected value of the lagged dependent variable.
[c] Regression results for PSC are: adjusted multiple R-squared statistic ($\bar{R}^2$) = .955, standard error of estimate (SY) = 1.185, and Durbin-Watson statistic (DW) = 2.039. For PHC: $\bar{R}^2$ = .955, SY = 1.164, and DW = 1.944. For PSC − PHC: $\bar{R}^2$ = .074, SY = .546, and DW = 1.703.

simultaneity, all right hand side variables suspected as jointly endogenous (see Table 1) were estimated as instrumental variables, permitting consistent and asymptotically efficient estimates (Hanssens and Liu).[2]

Empirical Results

Tables 2 through 9 present the regression results of the steer and heifer prices and their estimated price flexibility coefficients. The latter are estimated for selected time periods, based upon the distributed lag behavior of the dependent variables.[3] All the ensuing equations represent, statistically, the best estimates since model tests revealed no superior specification of distributed lags and order of autocorrelation.

[2] In Table 1 all the independent variables considered as endogenous were estimated as instrumental variables from a set of reduced form equations. Theoretically, their predicted values (used as the instruments) are uncorrelated in the limit with disturbance terms in the structural equations.

[3] A mathematical algorithm using a recursion formula was used to calculate the partial derivatives of the dependent variables with respect to changes in the independent variables. These time paths of the endogenous variables, or their distributed lag behavior, served as the basis to estimate the various length of run price flexibilities presented in the appropriate tables.

Steer and Heifer Carcass Prices

Steer and heifer carcass prices are estimated as geometric distributed lags (i.e., first order difference equations). First order serial correlation was not significant. Table 2 presents the statistical results of the regression equations. Table 3 presents the price flexibility coefficients for different time periods. All asymptotic t values (except those of the intercepts) indicate the coefficient estimates are significantly different from zero at the 95 percent probability level. The geometric lag effects of the independent variables decline relatively slowly because of the large estimated coefficients on the lagged dependent variables (0.96 and 0.94).

The coefficient estimate of the pork and poultry production variable, QPKPY, has a positive sign. This result appears contrary to theoretical reasoning since a negative effect would be expected with competitive meat supplies. Brester and Marsh showed such substitutes to be significant with the correct sign in a retail beef price equation. However, Freebairn and Rausser and Hayenga and Hacklander encountered sign problems with substitutes in retail beef demand equations. They attributed such results to consumer preference for variety in diet menu. Since the collinearity of QPKPY with other variables is

TABLE 2. Extended.

Variables[a]						
QPKPY	BPVC	BPVC − 1	Y	Y − 1	MCR	E(DEP − 1)[b]
1.978	11.572	−7.417	.023	−.016	−.442	.959
(7.676)	(4.210)	(−2.657)	(4.805)	(−3.608)	(−4.838)	(14.441)
1.813	13.055	−8.613	.021	−.015	−.382	.942
(6.967)	(4.920)	(−3.128)	(4.407)	(−3.402)	(−4.231)	(13.704)
—	—	—	—	—	—	—

not serious, we conclude that this variety preference may be reflected back to the wholesale market.

Steer and heifer carcass production (QSHC) is specified to measure the effect of wholesale beef production on steer and heifer carcass prices. For each equation, the sum of the regression coefficients for periods t and t − 1 is negative, which is in agreement with a negative relationship between prices and quantities.[4] In Table 3 the price flexibilities reflect a slow geometric adjustment rate. Through the first eight quarters it appears that heifer price may be slightly more sensitive to production changes than steer price. Estimates for the long-run indicate the opposite (based only upon arithmetic differences in the price flexibilities). It also can be seen that the price flexibilities increase with time, indicating that carcass prices more completely adjust to changes in supply conditions in the market. The effects are cumulative, that is, a one time change in supply has its largest impact in the first time period, and then increases at a decreasing geometric rate. Some of the constraints that may cause this behavior include short-term price agreements or contracts between packers and retailers, fixed (short-term) processing and storage capacity, and perhaps incomplete market information.[5]

The value of carcass by-products is highly significant in affecting short- and long-run steer and heifer carcass prices. The positive correlation is expected since increases in the value of by-products increase the per unit values of steer and heifer carcasses. The heifer carcass price appears to be more sensitive in the short-run while the steer price appears more sensitive in the long-run (based on arithmetic differences of the price flexibility coefficients). For a period of one quarter, a 10 percent increase in the value of by-products leads to an increase in steer and heifer prices by 3.0 and 3.5 percent, respectively. Over the long-run, the same 10 percent increase produces a 26.2 and 20.7 percent increase in the respective carcass prices.

Real disposable income is a shifter of primary demand, reflecting changes in consumer purchasing power. These income changes are reflected back to the steer and heifer carcass market through purchases by retailers. The results reveal a positive income effect. For example,

[4] Quantities of steer carcass production and heifer carcass production were tested as separate regressors. However, their high collinearity precluded significant asymptotic t ratios, and, also, produced coefficient signs inconsistent with theoretical reasoning.

[5] Such short term constraints are not explicitly modeled because of data limitations. However, one virtue of the difference equation approach is that the lagged dependent variable captures short term rigidities in the market. In the carcass price equations, the large difference equation coefficients suggest that sufficient time is required to overcome the mentioned constraints. This is not surprising due to the time involved in beef demand changes and in adjusting plant size and technology.

TABLE 3. Partial Derivatives and Price Flexibilities of the Distributed Lags in the Steer and Heifer Carcass Market.

Equation	Quarters[a]				Long-run
	1	2	4	8	
PSC/QSHC	−13.638	−15.769	−19.769	−26.822	−65.105
	(−.700)	(−.809)	(−1.014)	(−1.376)	(−3.340)
PHC/QSHC	−14.150	−16.506	−20.820	−28.054	−55.081
	(−.744)	(−.868)	(−1.094)	(−1.475)	(−2.895)
PSC/BPVC	11.572	15.249	22.151	34.324	100.39
	(.302)	(.399)	(.579)	(.897)	(2.624)
PHC/BPVC	13.055	16.746	23.502	34.832	77.163
	(.350)	(.448)	(.629)	(.933)	(2.066)
PSC/Y	.023	.030	.042	.063	.178
	(1.770)	(2.308)	(3.231)	(4.847)	(13.695)
PHC/Y	.021	.026	.035	.051	.109
	(1.655)	(2.049)	(2.759)	(4.020)	(8.592)
PSC/MCR	−.442	−.866	−1.661	−3.064	−10.676
	(−.330)	(−.647)	(−1.241)	(−2.289)	(−7.975)
PHC/MCR	−.382	−.741	−1.400	−2.504	−6.629
	(−.292)	(−.567)	(−1.071)	(−1.916)	(−5.073)
PSC − PHC/QSHC[b]	.899	—	—	—	—
	(1.928)				

[a] The top figures represent the partial derivatives and the figures below in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure represents the cumulative effects over the indicated quarterly periods.

[b] Carcass price difference equations were estimated as static models; therefore, partial derivatives and price flexibilities were calculated for the first quarter only.

within a period of one quarter, a $100 increase in income will lead to an increase in steer carcass price by 2.3 cents per pound and heifer carcass price by 2.1 cents per pound. The estimated income flexibility coefficients are highly significant, showing values greater than unity for all time periods.

The carcass-to-retail marketing margin variable is specified to capture the effect of changes in per unit processing and distribution costs on the prices of steer and heifer carcasses. The absolute values of the price flexibility coefficients are less than unity for a time period of less than one year, but are "flexible" (>1.0) for a period of one year or more. This suggests that if there is an increase in distribution costs, in the shorter term, retailers may absorb more of the cost increase (or pass it on to consumers) since they may be temporarily locked in on purchase price agreements with packers.[6] Over time, however, retailers can adjust their purchase price offers (on wholesale meat) in accordance with changes in costs they face.

The directly estimated difference between steer and heifer carcass prices (PSC − PHC) is reported in Table 2. The regression results reveal that the only significant exogenous variable (at the 90 percent level) to influence steer price premiums is the production of steer and heifer carcasses. The positive regression coefficient is consistent with the results of the

[6] Usually these arrangements are through "negotiated" transactions or "formula pricing." For example, under the former if a packer agrees to ship a certain quantity and quality of meat to a retailer in 60 days, the price is negotiated at the time of the agreement. Under formula pricing, if a packer agrees to ship a certain quantity and quality of meat in 60 days, the price agreed upon is the one that would be listed on the Yellow Sheet near the day of delivery.

individual carcass price equations. That is, increases in carcass production decrease both steer and heifer carcass prices, but heifer prices relatively more. For example, in Table 3 the price flexibility coefficients show that, for a period of one quarter, a 10 percent increase in carcass production reduces steer carcass prices by 7.0 percent and heifer carcass prices by 7.4 percent. The difference relates to the gender component of slaughter. The sample data show that significant increases in carcass production stems from increased slaughter numbers and/or dressed weights of steers and heifers. Often when there is an increase in slaughter numbers relatively more heifers enter slaughter, particularly in the deceleration stage of the cattle cycle (the years 1971–77 in the sample data). Since the distribution of weights between steer and heifer carcasses changes little, the additional heifer slaughter yields relatively more total heifer carcass weight than steer carcass weight.

The adjusted R^2 is extremely low, indicating that the effects of seasonality and production on steer-heifer carcass price differences are quite minimal. This leaves a large impact due to the stochastic error term, which may be attributed to several factors. One may be variation in quality, as heifer carcasses (even within the same yield grade) are not always as well marbled, showing more fat deposits on the outside of the meat. Another may reflect higher per unit processing costs for heifers since heifer carcasses average lighter in weight than steer carcasses. Also, over time, there may be random errors due to variations in the grading (quality and yield) of steer and heifer carcasses.

Slaughter Market

The slaughter steer and heifer price equations are estimated as static functions with no significant serial correlation. Its static nature is not surprising since buying cattle and selling carcasses and fabricated

TABLE 4. Statistical Results of Quarterly Slaughter Steer and Heifer Prices and Price Difference.

	Variables[a]								Statistics[b]		
Equation	Constant	D2	D3	D4	PSC	BPVF	QFS	QNFS	$\bar{R}^2$	SY	DW
PSS	3.331	.203	.276	−.045	.540	.483	−.689	−1.719	.957	.798	1.839
	(1.649)	(.603)	(.807)	(−.131)	(19.149)	(5.008)	(−1.359)	(−2.503)			
PSH	5.080	.090	.184	−.040	.493	.487	−.849	−2.127	.951	.802	2.222
	(2.500)	(.265)	(.536)	(−.115)	(17.406)	(5.014)	(−1.644)	(−3.079)			
PSS − PSH	−.840	.139	.107	−.010	.038	—	—	—	.331	.372	1.989
	(−1.424)	(1.088)	(.747)	(−.075)	(2.718)						

[a] The asymptotic t ratios are given in parentheses below each coefficient. The critical boundary is 2.021 for a 95 percent probability level (degrees of freedom are 40).

[b] $\bar{R}^2$ = adjusted multiple R-squared statistic.
SY = standard error of the estimate.
DW = Durbin-Watson statistic.

TABLE 5. Partial Derivatives and Price Flexibilities in the Slaughter Steer and Heifer Market.

	Variables[a]			
Equation	PSC	BPVF	QFS	QNFS
PSS	.540	.483	−.698	−1.719
	(.847)	(.126)	(−.076)	(−.026)
PSH	.493	.487	−.849	−2.127
	(.797)	(.131)	(−.095)	(−.033)
PSS − PSH	.038	—	—	—
	(1.969)			

[a] The top figures represent partial derivatives and the figures in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure is representative of a first quarter effect of an independent variable on a dependent variable.

products are performed by the same firm. Cattle buying is highly influenced by changes in wholesale prices; thus, rather quick adjustments in slaughter prices would be expected. The independent variables include the contemporaneous price of steer carcasses, by-product values, and the quantities of fed and nonfed slaughter. The price of steer carcasses enters the slaughter price equations as an instrumental variable due to its endogenous nature in the model. Table 4 gives the statistical results for steer and heifer slaughter prices while Table 5 presents the estimated price flexibilities.

The market prices of beef carcasses and by-products (meat packer output) play a major role in the pricing of slaughter steers and heifers. This is confirmed by positive coefficients that have highly significant asymptotic t ratios. A 10 percent increase in the price of steer carcasses results in an 8.5 percent increase in the slaughter steer price and an 8.0 percent increase in the slaughter heifer price. These results indicate that an increase in the market value of carcasses increases the derived demand for slaughter inputs, hence slaughter prices.

By-product values in the slaughter sector reflect the prices of hide and offal products and usually pay for slaughter costs and profit margins (since carcass value is usually less than live animal value). Consequently, when their values increase, the overall value of the live animal increases. This hypothesis is supported by the positive sign of the coefficient estimate. The price flexibility coefficient shows that a 10 percent increase in the value of by-products increases steer and heifer slaughter prices by 1.3 percent.

The quantities of fed and nonfed slaughter are specified to account for supplies of steers and heifers marketed from feedlots and ranches, respectively. Their negative coefficient signs are consistent with economic theory.[7] Based on the price flexibility coefficients, the results show that fed slaughter has a greater direct impact on steer and heifer prices than does nonfed slaughter (i.e., about three times as great). This is expected since nonfed cattle slaughter, which consists of cull stock and range fed steers and heifers, competes with fed slaughter and is considered to be of lower quality (Osprina and Shumway).

The equation specification for the slaughter steer and heifer price difference (PSS − PSH) initially included the same set of exogenous variables as did the individual equations. However, the price of steer carcasses was found to be the only statistically significant variable (prices of steer and heifer carcasses were specified as separate independent variables, however, high collinearity precluded their individual statistical significance). The steer carcass price variable, PSC, is positively correlated with the steer-heifer price difference. The reason for its positive effect is based on the relationship between the carcass and live slaughter markets. To meat packers, variables influencing the output market (i.e., carcass and boxed beef sales) directly impact the input market

[7] Commercial slaughter of steers and commercial slaughter of heifers were also specified as separate regressors in the slaughter price equations. However, strong collinearity among those variables yielded insignificant asymptotic t ratios.

TABLE 6. The Statistical Results of Quarterly Steer and Heifer Feeder Prices and Price Differences.

		Variables[a]									Statistics[b]		
Equation	Constant	D2	D3	D4	PSS	QFS	QFH	PC	MFC	E(DEP − 1)	$\bar{R}^2$	SY	DW
PFS4–5	−18.859	−.675	−.494	1.138	1.039	2.684	7.629	−1.911	−1.958	.491	.971	1.508	1.957
	(−4.009)	(−.996)	(−.546)	(1.367)	(9.074)	(1.343)	(2.171)	(−1.724)	(−3.946)	(6.940)			
PFH4–5	−18.058	−.258	.369	1.245	.859	3.145	6.772	−1.833	−1.765	.487	.976	1.192	1.979
	(−4.890)	(−.481)	(.513)	(1.841)	(9.419)	(1.974)	(2.449)	(−2.111)	(−4.489)	(7.535)			
PFS4–5 − PFH4–5	−2.866	−.268	−.721	.087	.176	−.745	2.364	—	—	.459	.750	.570	2.022
	(−2.801)	(−1.060)	(−2.694)	(.328)	(4.292)	(−2.518)	(3.375)			(3.400)			
PFS6–7	−13.984	−.568	.116	1.706	.939	2.735	4.895	−1.064	−1.624	.383	.965	1.239	1.990
	(−3.491)	(−1.034)	(.156)	(2.471)	(9.686)	(1.623)	(1.659)	(−1.126)	(−4.003)	(4.735)			
PFH6–7	−12.118	−.295	.570	1.540	.809	3.215	3.908	−1.310	−1.685	.385	.972	1.002	1.990
	(−3.737)	(−.659)	(.926)	(2.659)	(10.293)	(2.304)	(1.627)	(−1.705)	(−5.123)	(5.248)			
PFS6–7 − PFH6–7	−1.743	−.293	−.464	.175	.136	−.447	1.017	.211	—	.348	.808	.345	1.787
	(−2.068)	(−2.038)	(−2.712)	(1.107)	(5.328)	(−1.411)	(1.552)	(.900)		(2.230)			

[a] The asymptotic t ratios are given in parentheses below each coefficient. The critical boundary is 2.030 for a 95 percent probability level (degrees of freedom are 36).

[b] $\bar{R}^2$ = adjusted multiple R-squared statistic.
SY = standard error of the equation.
DW = Durbin-Watson statistic.

(purchases of slaughter cattle) since profit margins are affected. Thus, for example, if retailers were bidding higher for steer carcasses, to meet that demand packers would demand more live steers (relative to heifers) for slaughter.

The adjusted R^2 is small at .33, however, larger than found in the steer-heifer carcass price difference equation. Though the systematic portion of the equation indicates that increasing levels of steer meat prices tend to increase the slaughter steer-heifer price difference, random factors still explain the greatest proportion of the variation in the dependent variable. Some of these factors may include variations in preferences by packers for steers versus heifers, changes in beef grades, and variations in judging quality differences between steers and heifers when they are purchased from feedlots and ranches.

Feeder Market

The statistical results for the 400–500 pound and 600–700 pound feeder steer and heifer price equations are presented in Table 6. All models were estimated as first order difference equations with positive first order serial correlation. The sizes of the coefficients on the lagged dependent variables are relatively small, indicating that the rates of geometric decline (or the distributed lag effects of the independent variables) are relatively rapid.

Slaughter steer price (PSS) is crucial in determining the prices of feeder steers and heifers in both weight categories. The rationale is that this variable represents the value of output to feedlots; thus, its change affects placement demand for feeders. There appears to be a noticeable, but not major, difference in the effect of slaughter price on feeder steer and heifer prices across weight categories. That is, the regression coefficients (and price flexibilities) show that the prices of feeder steers and heifers in the 400–500 lb. weight range to be more highly impacted than the prices of steers and heifers in the 600–700 lb. weight range. The difference may relate to minimizing feeder purchase costs. Other variables constant, when slaughter price increases it becomes more economical for feedlot operators to buy relatively lighter weight cattle. Thus, prices of lighter cattle increase relatively more than those for heavier cattle, a result also encountered by Buccola.

The price of corn serves as a proxy for cost of gain in the feedlot. Work by Buccola and Jessee (1979) and Marsh (1983) have shown corn prices to significantly influence derived demand, hence, prices of feeder cattle. Results of this study show the correct signs (negative) but not particularly large asymptotic t ratios, particularly with respect to the price of 600–700 pound feeder steers. The price flexibilities reveal that, for a period of four quarters, a 10 percent increase in corn price decreases light cattle prices (for both sexes) about 1.7 percent, heavier steers .8 percent, and heavier heifers 1.2 percent. These results reflect rational adjustments by cattle feeders to keep the cost of gain in feedlots at near minimum levels when grain prices change. That is, when feed costs increase, relatively heavier cattle are fed since time on feed is shorter, though demand for both feeder weight classes declines. Also, since feed conversion is less efficient for heifers, relatively more steers (compared to heifers) are placed on feed. These results are consistent with Buccola's measurement of the effect of the cost of feed on cattle price-weight slopes.

The negative effect of the marketing margin (MFC) is consistent with theoretical precepts, since an increase in marketing costs reduces the derived demand for steers and heifers. Its impact is not much different on steer prices than on heifer prices. That is, for a period of one quarter, a 10 percent increase in the margin shows an approximate three percent decrease in prices for light and heavy cattle of both sexes. Over time, the long-run price flex-

TABLE 7. Partial Derivatives and Price Flexibilities of the Distributed Lags in the Feeder Steer and Heifer Market, 400–500 lbs.

	Quarters[a]				
Equation	1	2	4	8	Long-run
PFS4–5/PSS	1.039	1.548	1.922	2.034	2.040
	(.885)	(1.318)	(1.637)	(1.732)	(1.737)
PFH4–5/PSS	.859	1.277	1.580	1.669	1.675
	(.869)	(1.292)	(1.599)	(1.689)	(1.695)
PFS4–5/PC	−1.911	−2.849	−3.536	−3.742	−3.754
	(−.085)	(−.127)	(−.157)	(−.166)	(−.167)
PFH4–5/PC	−1.833	−2.726	−3.373	−3.563	−3.575
	(−.097)	(−.144)	(−.178)	(−.188)	(−.189)
PFS4–5/MFC	−1.958	−2.919	−3.623	−3.833	−3.846
	(−.295)	(−.440)	(−.546)	(−.577)	(−.579)
PFH4–5/MFC	−1.765	−2.625	−3.248	−3.431	−3.441
	(−.316)	(−.470)	(−.581)	(−.614)	(−.616)

[a] The top figures represent the partial derivatives and the figures below in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure represents the cumulative effects over the indicated quarterly periods.

ibilities become less inflexible, yet less than unity.

The respective steers and heifers on feed variables, QFS and QFH, are included to measure the effect of relative inventory supplies. Statistical results indicate they are positively correlated with the dependent price variables (for each sex and weight category), which conflicts with theoretical expectations of negative price and quantity relationships. It is suspected that strong joint dependency exists between cattle on feed and feeder prices. An effort to eliminate joint dependency included estimating QFS and QFH as instrumental variables; however, it was unsuccessful.

The regression fits of feeder steer and heifer price differences (PFS4–5 − PFH4–5 and PFS6–7 − PFH6–7) are significantly greater than found at the other market levels (Table 6). The statistical results also show that the price differences are characterized by geometric distributed lags as evidenced in the individual price equations. All parameter signs meet a priori expectations.

The effect of a change in the price of slaughter steers is similar to that found in the individual price equations. That is, an increase in slaughter steer price leads to an increase in the derived demands (hence prices) for both steer and heifer feeder inputs; however, there is a relatively greater increase in demand for feeder steers. With a 10 percent increase in slaughter steer price, over a period of four quarters, feeder steer and heifer price differences for both weight categories increase about 17 percent (Table 9). Such behavior is traceable to the nature of the vertical relationship between the slaughter and feeder sectors in the livestock market channel. If packers demand relatively more slaughter steers (compared to heifers), this yields a price signal to cattle feeders which results in rational purchasing behavior. That is, to increase finishing returns, feeders would demand relatively more feeder steers for placement, increasing the price spread.

The supply variables demonstrate an inverse relationship between prices and quantities. Logically one would expect that an increase in the number of steers on feed would decrease the steer-heifer price spread, while an increase in the number of heifers on feed would increase it. The price flexibilities in Table 9 support this

TABLE 8. Partial Derivatives and Price Flexibilities of the Distributed Lags in the Feeder Steer and Heifer Market, 600–700 lbs.

Equation	Quarters[a] 1	2	4	8	Long-run
PFS6–7/PSS	.939	1.299	1.490	1.522	1.523
	(.882)	(1.221)	(1.400)	(1.430)	(1.431)
PFH6–7/PSS	.809	1.120	1.285	1.313	1.314
	(.860)	(1.190)	(1.366)	(1.396)	(1.397)
PFS6–7/PC	−1.064	−1.472	−1.688	−1.725	−1.726
	(−.052)	(−.072)	(−.083)	(−.084)	(−.085)
PFH6–7/PC	−1.310	−1.813	−2.082	−2.127	−2.128
	(−.073)	(−.101)	(−.116)	(−.118)	(−.118)
PFS6–7/MFC	−1.624	−2.247	−2.577	−2.633	−2.634
	(−.270)	(−.374)	(−.428)	(−.438)	(−.439)
PFH6–7/MFC	−1.685	−2.333	−2.678	−2.736	−2.738
	(−.317)	(−.439)	(−.504)	(−.514)	(−.515)

[a] The top figures represent the partial derivatives and the figures below in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure represents the cumulative effects over the indicated quarterly periods.

hypothesis for both weight categories. Such results are also consistent with work by Buccola and Jessee on regional steer-heifer price differences, where larger steer to heifer inventory ratios in cattle feeding regions decreased the steer price premium.

Interestingly, the cost of gain variable (PC) is not significant in the light cattle price difference equation and is only marginally significant in the heavier cattle price difference equation. The coefficient signs are consistent with the effects of feed prices found by Buccola and Jessee, but the statistical significance here is considerably less. Such might be the case in this model since the data averages across all regions. Price flexibility estimates show that a 10 percent increase in corn price increases the price spread between 600–700 lb. steers and heifers by only 1.4 percent over a period of four quarters. These results suggest that cattle feeders may not be very sensitive to steer-heifer feed conversion differences when cost of gain changes. That is, when feed costs increase, price reductions for both steers and heifers are nearly equal. One reason may be that even though heifers require more feed per pound of gain, finishing weights are lighter, thus, they are on feed a smaller number of days (than steers). Another reason may be that feed conversion differences are not overly large, ranging from seven to 10 percent between steers and heifers, depending upon weights and grades (SBCN).

Concluding Remarks

Some producers in the cattle industry feel that heifer price discounts (particularly at the feeder level) are too large, and therefore are economically unwarranted. Perhaps on a local basis some cattle feeders and stocker operators may have certain preferences against heifers. Since the dynamic model used time series data that averages across all firms and regions, such allegations are difficult to prove. However, the geometric adjustments of feeder steer and heifer price differences may provide some information. First, the model revealed that 75 and 80 percent of the variations in sex price differences for calves and yearlings, respectively, were explained by seasonal and economic variables. These factors would not constitute

TABLE 9. Partial Derivatives and Price Flexibilities of the Distributed Lags for the Price Differences in Feeder Steers and Heifers, 400–500 lbs. and 600–700 lbs.

Equation	Quarters[a] 1	2	4	8	Long-run
PFS – PFH4–5/PSS	.176	.256	.310	.324	.325
	(.946)	(1.376)	(1.666)	(1.741)	(1.747)
PFS – PFH4–5/QFS	−.745	−1.087	−1.316	−1.374	−1.377
	(−.452)	(−.660)	(−.799)	(−.834)	(−.836)
PFS – PFH4–5/QFH	2.364	3.448	4.175	4.360	4.368
	(.674)	(.983)	(1.190)	(1.243)	(1.245)
PFS – PFH6–7/PSS	.136	.184	.206	.209	.209
	(1.103)	(1.492)	(1.671)	(1.695)	(1.695)
PFS – PFH6–7/QFS	−.447	−.603	−.676	−.686	−.686
	(−.409)	(−.552)	(−.619)	(−.628)	(−.628)
PFS – PFH6–7/QFH	1.017	1.371	1.538	1.560	1.561
	(.437)	(.590)	(.662)	(.671)	(.671)
PFS – PFH6–7/PC	.211	.284	.319	.323	.324
	(.089)	(.120)	(.135)	(.137)	(.137)

[a] The top figures represent the partial derivatives and the figures below in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure represents the cumulative effects over the indicated quarterly periods.

economically unwarranted price differences unless, however, one was suspicious of the steer-heifer carcass and slaughter price spreads. Second, the dynamics of the model indicate that, given shifts in the exogenous variables, feeder steer and heifer price differences stabilize, or approach equilibrium levels rather quickly.

The effect of the remaining 20 to 25 percent unexplained variation is open to speculation. However, two important characteristics of the beef industry could play a role here. One is risk of placing pregnant heifers in a feedlot, the other is competition from heifers placed in the breeding herd. The risk of placing nonopen heifers in feedlots may vary among cattle feeders since knowledge about their pregnancy status is not uniform (i.e., some feeders may or may not pregnancy test), and use of abortifacients is not uniform. Thus, in the aggregate, adjusting a heifer price discount to account for this problem may be random. Heifer retention for the breeding herd could also fit in the error structure because of weather conditions and different financial constraints among production units. Thus, over time, decisions about heifer replacement rates will vary because of these factors, i.e., reduced herd replacements in areas of drought and in periods of financial stress. Such actions affect the feeder steer-heifer price spread because of the relative changes in demand for breeding heifers.

Finally, with the explanatory power of the residuals larger than one would prefer, there is always suspicion of temporary economically unwarranted price differences between steers and heifers. In the very short term, such anomalies might occur. However, as time increases, it would be difficult for unwarranted price differences to persist. The profit motive would cause, through competition, firms at each market level and buyers and sellers in the vertical market channel to bring steer-heifer price spreads into equilibrium.

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