AN ANALYSIS OF FEEDER STEER-HEIFER PRICE DIFFERENTIALS IN THE U.S.

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CHAPTER I

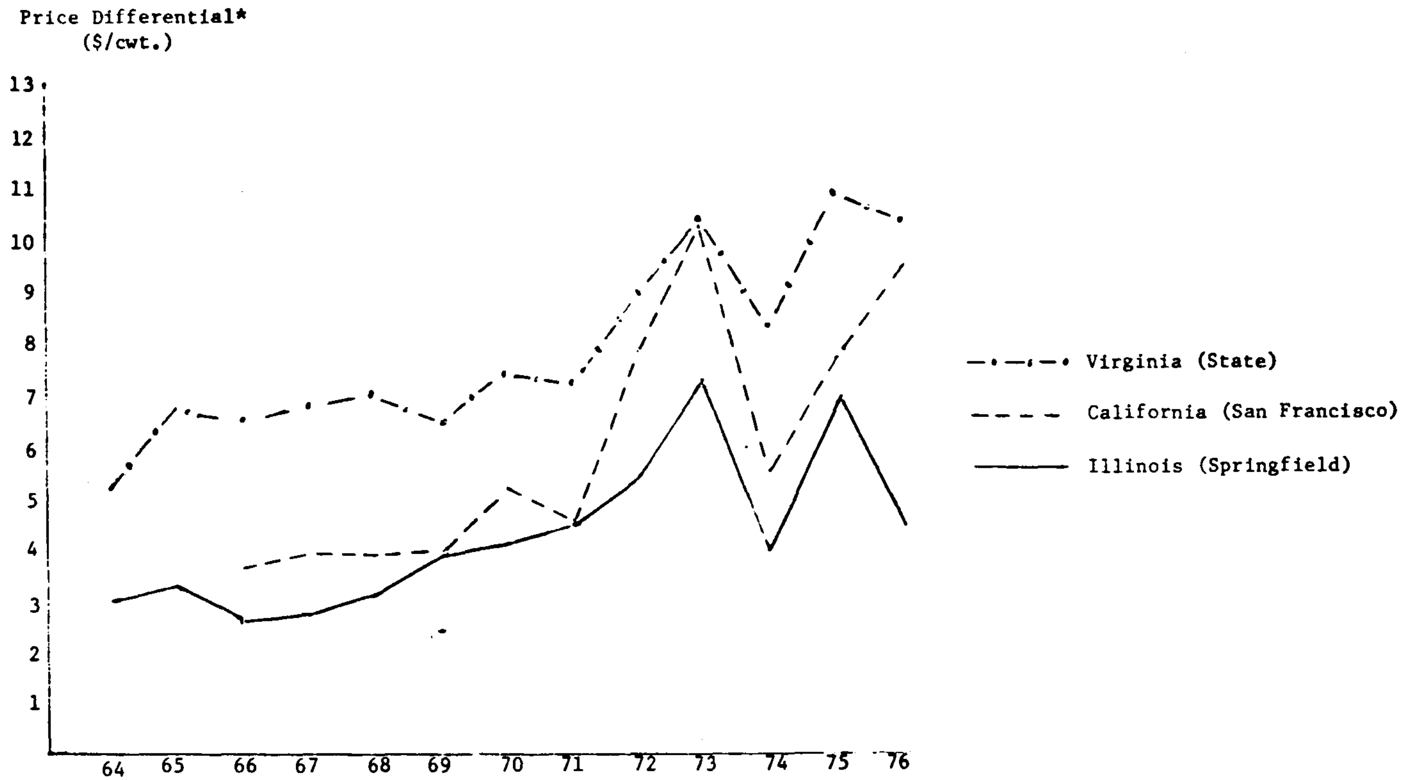
INTRODUCTION

In a market economy, prices have the function of allocating resources among competing uses. According to the theory of a perfect market an efficient system establishes prices which are functionally related to space, time, and form utilities. Breimyer suggests that in the livestock-meat industry, competition is as nearly perfect as found anywhere.

However, pricing imperfections[1/] may exist in the livestock industry since uniform grade standards have not been adopted, and a large proportion of feeder sales are unreported, which may limit price information. Specific studies of local situations may determine how actual prices compare with the perfect or efficient model. These studies may provide a basis for appraising pricing efficiency.

Overall Problem

Some evidence shows that market equilibrium steer-heifer price differentials are not constant over time and space within the United States. In particular, the spread in Virginia steer-heifer calf prices in recent years has been notably higher than the national average (Wise). Figure 1.1 compares levels of the steer-heifer feeder calf price differential from 1964 through 1976 for Virginia and two other markets.[2/] These facts raise concern regarding the pricing efficiency of Virginia's feeder cattle market because in an efficient system price differences should reflect cost differences.



*Choice, 400-500 lb. steer price minus choice, 400-500 lb. heifer price; unweighted Sept.-Oct.-Nov. average.

Figure 1.1. Price Differential Between Steer and Heifer Calves for Three Markets, 1964-1976

The question then becomes: Are observed sex price relationships in the Virginia feeder cattle market consistent with time, place, and form transformations, assuming buyers and sellers maximize expected profit? A priori, is there any reason to expect that heifer calves in Virginia are less valuable, relative to steer calves, than heifer calves in some distant market?

Problem Statement

In order to test the hypothesis that the marketing system is performing efficiently in pricing heifer calves relative to steers, attributes which determine their relative value at one point in a space-time-form coordinate must be identified.

The overall objective of this study is to identify the major factors which contribute to the variation in the steer-heifer price spread as a measure of relative value.

Attention is focused upon Virginia feeder calf sales since Virginia is primarily a beef cow-calf producing state. Comparisons are made with selected feeder calf markets throughout the U.S. The usefulness of this research effort is to provide some indication whether the pricing mechanism is performing accurately in reflecting market demand and supply for feeder cattle. The sex price differential is important to cow-calf producers because of its impact upon cow-calf operators' income: to a producer, an increasing heifer discount may represent a loss of income. Also, since nearly all price forecasting models relate to steers rather than heifers, and since futures market transactions exclude heifers, knowledge of the sex price spread could help provide more information for price forecasting models.

Specific Objectives

The specific objectives of this study are: (1) to establish whether or not the Virginia steer-heifer feeder price spread is significantly greater than in other U.S. regions; (2) to identify those physical and economic attributes which differentiate steers from heifers over the time and space dimensions; (3) to specify the interrelationships between these attributes and the market sex price differential as a measure of relative value; (4) to provide a basis for judging any divergence between actual and "perfect market" sex price spreads.

1/ Pricing imperfections refer to the extent to which prices fail to reflect value.

2/ See Chapter III for procedure used in calculating prices.

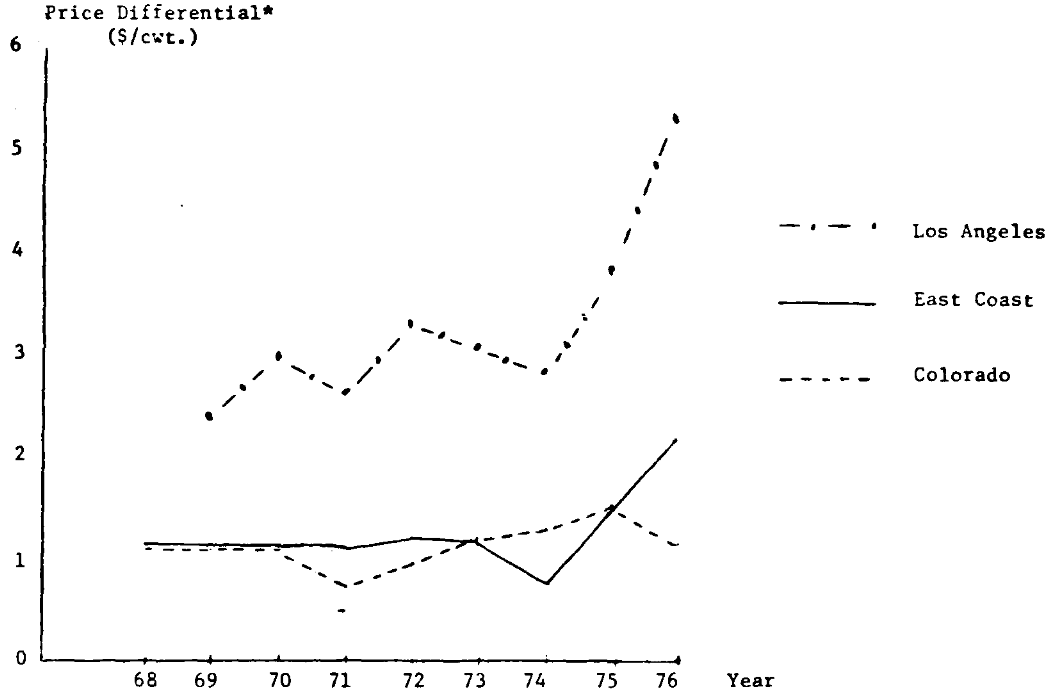
CHAPTER II

THEORETICAL FRAMEWORK

Model Development

In order to arrive at the basic cause of variation in steer-heifer price spreads, several attributes which differentiate steers from heifers must be recognized:

1. Heifers are less efficient than steers in converting feed to gain, resulting in higher feed costs per unit weight of gain for heifers.[1/]
2. Quantities of feeder heifers offered for sale during any market period may be expected to behave differently in response to production cost and output price changes than would quantities of feeder steers, since some heifers must be retained for breeding purposes and are fed for shorter periods to lighter weights.
3. Retailers and wholesalers discriminate steer carcasses from heifer carcasses;[2/] furthermore, it appears that the price differential between steer and heifer carcasses is higher in some regions than in others (Figure 2.1). To the extent that this discrimination affects the fed cattle sex price spread, it may influence the feeder sex price spread. However, wholesale beef and slaughter cattle movement data are unavailable, precluding any analysis of the influence of wholesale sex price differentials upon the feeder sex price differential.



*Choice 600-700 lb. steer beef price minus choice, 500-600 lb. heifer beef price. Wholesale dressed meat price, carlot basis; annual unweighted monthly average.

Figure 2.1. Price Differential Between Wholesale, Dressed Steer and Heifer Beef, 1968-1976, At Three Specified Markets.

The economic forces which give rise to the feeder sex price differential must arise somewhere between basic demand at the retail level and basic supply in the production of weaned calves since: (1) consumers do not discriminate steer beef from heifer beef; and (2) the ratio of bull calves to heifer calves produced is fixed biologically in an approximate 1:1 proportion. The result is that consumers cannot respond to changing steer-heifer price relationships be altering their purchase patterns, and cow-calf farmers cannot respond by changing the relative quantities of bull and heifer calves produced. However, as will be explored later, farmers can control the relative quantities offered for sale.

To conceptualize a model for explaining changes in the steer-heifer feeder price spread, each of the variables identified in Blakely's structural derivation of the feeder cattle market are first examined. It is hypothesized that some of these variables do not affect the supply and demand relations for steers and heifers identically due to the three attributes mentioned previously. It follows from this hypothesis that steer-heifer price relationships do not remain constant as these variables change (from one time period or market region to another).

The derived demand quantity of feeder cattle is hypothesized to be a function of the feeder price (input price), the fed cattle price (output price) and feed cost per unit of liveweight gain (input cost).[3/]

The quantity supplied of feeder cattle is assumed to be a function of the feeder price (output price), feed costs for backgrounding cattle (input costs) and the inventory of brood cows in some previous period.

Derived Demand for Feeder Steers and Heifers

Theoretically, a fed cattle producer's demand relation for either steers or heifers could be represented as:

(2.1) $$Q^d_{fs} = f_1(Pfs, PFs, FCs)$$

(2.2) $$Q^d_{fh} = f_2(Pfh, PFh, FCh)$$

where:

Q^d_{fs}, Q^d_{fh} = quantity demanded of feeder steers or heifers.

Pfs, Pfh = price per unit weight of feeder steers or heifers.

PFs, PFh = price per unit weight of fed steers or heifers.

FCs, FCh = feed costs per unit liveweight gain for heifers or steers in the feedlot.

Conceptually, equations (2.1) and (2.2) could be specified in terms of differences, allowing a comparison between steers and heifers:

(2.3) $$Q^d_{fs} - Q^d_{fh} = f_3[(Pfs - Pfh), (PFs - PFh), (FCs - FCh)].$$

where the difference in quantity demanded is functionally related to price and cost differences.

According to the theory of derived demand, the quantity demanded of an input is negatively related to its own price, positively related to output price, and negatively related to input cost. Thus, a priori reasoning suggests that the demand quantity difference, $(Q^d_{fs} - Q^d_{fh})$, is negatively related to the feeder sex price differential (Pfs - Pfh), positively related to the fed cattle sex price differential, (PFs - PFh), and negatively related to the steer-heifer feed cost differential, (FCs - FCh).

Supply of Feeder Steers and Heifers

In conceptualizing the supply relation for steers and heifers, it must be noted that:

1. The birth ratio of steers to heifers is approximately 1:1. Further, cow-calf farmers are unable to change the quantities of steers and heifers produced within a one-year period, since it requires more than a year to breed a female and produce a weaned calf. However, cow-calf farmers can influence the relative quantities of heifers to steers offered for sale -- and the relative quantities may depend upon expected returns to calf production.
2. Steers are usually preferred to heifers for wintering because steers make larger gains than do heifers on non-fattening feeds; also, to prevent breeding and possible pregnancy, farmers are not so apt to hold heifers over the winter for sale as yearlings (Neumann and Snapp, p. 330-332).

The supply of feeder steers or heifers may be represented functionally as:

(2.4) $$Q^s_{fs} = f_4(Pfs,\ BCs,\ ICOW)$$

(2.5) $$Q^s_{fh} = f_5(Pfh,\ BCh,\ ICOW)$$

where:

Q^s_{fs}, Q^s_{fh} = quantity supplied of feeder steers or heifers;[4/]

Pfs, Pfh = price of feeder steers or heifers;

BCs, BCh = cost per unit weight of gain for backgrounding steers or heifers;

ICOW = farm inventory of brood cows (2 years or older).

Similar to the quantity demand difference function, (2.3), a quantity supply difference function could be specified:

(2.6) $$Q^s_{fs} - Q^s_{fh} = f_6[(Pfs - Pfh), (BCs - BCh)].$$

The inventory of brood cows is dropped from the model since the birth ratio of bull to heifer calves is approximately 1:1. One may expect that, over the long run, the expected profitability of raising calves would influence the quantity of heifers retained for breeding purposes, and thus, the relative quantities of heifers supplied. However, in the short run, cow-calf men may easily reduce brood cow culling rates rather than purchase additional heifers in response to a change in the expected profitability of calf production.

In (2.6), since according to economic theory a good's own price bears a positive relation to quantity supplied, and input cost is negatively related to quantity supplied, it is expected that the quantity supply difference bears a positive relation to the feeder sex price spread and a negative relation to the backgrounding cost differential between steers and heifers. However, as is discussed subsequently, an increase in backgrounding costs for heifers relative to steers may increase heifer marketings relative to steer marketings.

Combined Demand and Supply Model

Statistical estimates of (2.3) and (2.6) could be conceptualized to produce a simultaneous system of three equations:

$$(2.7)\quad Q^d_{fs} - Q^d_{fh} = B_0 + B_1(Pfs - Pfh) + B_2(PFs - PFh) + B_3(FCs - FCh) + e.$$

$$(2.8)\quad Q^s_{fs} - Q^s_{rh} = b_1(Pfs - Pfh) + b_2(BCs - BCh) + e.$$

$$(2.9)\quad (Q^d_{fs} - Q^d_{fh}) = (Q^s_{fs} - Q^s_{fh}).$$

where B_1 and b_1 are parameter estimates of a simultaneous system of equations. In (2.9), the quantity demand difference must equal the quantity supply difference to clear the market.

Since feeder cattle market transaction data are unavailable, and since the overall objective of this study is the identification of steer-heifer feeder price relationships, it appears more practical to estimate a reduced form with the steer-heifer feeder price differential, (Pfs - Pfh), taken as the dependent variable. Setting equations (2.7) and (2.8) equal by equation (2.9), collecting terms, and isolating the steer-heifer feeder price differential:

$$(2.10)\quad (Pfs - Pfh) = \left(\frac{b_0}{b_1 - B_1} - \frac{B}{b_1 - B_1}\right) + \left(\frac{b_2}{b_1 - B_1}\right)(BCs - BCh) + \left(\frac{B_2}{b_1 - B_1}\right)(PFs - Pfh) - \left(\frac{B_3}{b_1 - B_1}\right)(FCs - FCh) + e.$$

Combining the first two terms of (2.10) into a constant, B_0, and redefining new B's, a linear model of the steer-heifer feeder price spread is specified:

$$(2.11) \quad (Pfs - Pfh) = B_0 + B_1(BCs - BCh) + B_2(PFs - PFh) + B_3(FCs - FCh) + e.$$

Conceptual Basis for an Empirical Model

From the combined supply and demand model, an empirical model is developed. Two of the variables in (2.11) -- feed cost differences and backgrounding cost differences -- are re-specified since per pound cost of gain data from feedlots and cattlemen are unavailable for steers and heifers. Also two additional variables are specified: the proportion of heifers to steers on feed, which measures the tendency of feedlot operators to prefer one sex over the other; and the position in time on the cattle cycle, which measures the influence of expected prices on the relative quantities of heifers to steers marketed in the short run.[5/] These two variables are not derived from the independent supply and demand models since their effects do not arise in the classical feeder price model, which includes input costs and output prices as explanatory variables.

Each of the exogeneous variables is now theoretically specified, and *a priori* signs of the coefficients are discussed.

Fed Cattle Sex Price Spread. Economic theory would suggest that an increase in the price of slaughter steers, relative to slaughter heifers, will positively influence the steer-heifer feeder price differential, since an increase in the slaughter (output) price of steers, relative to heifers, will positively influence the demand price of feeder steers, relative to heifers.

<u>Feed Costs in the Feedlot</u>. As noted previously, it is necessary to re-specify the feed cost differential between steers and heifers, (FCs - FCh), since feed cost data for steers and heifers is unavailable for use in an empirical model. If we assume that heifers have a lower feed efficiency in the feedlot (i.e., a higher feed conversion ratio than do steers) it is possible to measure the effect of a feed cost differential (FCs - FCh) on the steer-heifer feeder price spread by observing feed prices.

Changes in feed costs per unit of liveweight gain for heifers or steers may arise due either to a change in feed ration prices (F) or a change in the feed conversion ratio (FCR):

(2.12) $$FCs = FCRs * F$$

(2.13) $$FCh = FCRh * F$$

where:

FCRs,h = feed conversion ratio on an as-fed basis for steers or heifers (unit weight of feed per unit of liveweight gain);

F = feed price for feedlot ration (dollars per unit weight of feed ration);

FCs,h = feed cost per unit liveweight gain for steers or heifers (dollars per liveweight gain).

Aggregate data pertaining to the feed costs per unit of liveweight gain (FCs,h) and feed conversion ratios (FCRs,h) for steers and heifers could not be obtained. However the effect of the feed cost differential can be quantified. Equation (2.12) is subtracted from equation (2.13) to obtain:

(2.14) $$FCh - FCs = F * (FCRh - FCRs)$$ 6/

Taking the partial derivative of the feed cost differential between heifers and steers, (FCh - FCs), with respect to feed prices (F), we obtain:

(2.15) $$\frac{d(FCh - FCs)}{dF} = FCRh - FCRs > 0$$

Note that since it is assumed that heifers are less feed efficient than steers (FCRh > FCRs), expression 2.15 is always positive and FCh - FCs is always positive.

Thus, an increase in feed ration prices widens the feed cost differential between heifers and steers, assuming that heifers are less feed efficient than are steers.

The significance of feed prices has been approached indirectly by Wise, and by Cooper, et. al. In both cases, it has been shown that under specified feed price conditions, there exists a feeder buying price differential, which equates the profitability of purchasing either steers or heifers for feedlot fattening. Intuitively, as feed prices increase, the breakeven buying (feeder) price differential should widen since fed cattle producers would be willing to pay a higher premium for feed efficient steers over heifers.

Table 2.1 is a summary of calculations to determine the breakeven steer-heifer feeder price differential based upon equal returns per dollar of cost for the feeder animal. The breakeven price differential is exhibited under a scheme of increasing feed prices while all other

Table 2.1. Breakeven Steer-Heifer Price Differentials Based Upon Equal Returns per Dollar of Feeder Animal Cost[a]

Price/cwt. Feed ($)	Price/bu. Corn ($)	Feeder Heifer Price/cwt. ($)	Steer price minus heifer price ($)
3.6	.905	32.85	3.15
3.9	1.21	32.63	3.37
4.2	1.51	32.28	3.62
4.5	1.82	32.12	3.88
4.8	2.12	31.83	4.17
5.1	2.43	31.51	4.49
5.4	2.74	31.15	4.85
5.7	3.04	30.76	5.24
6.0	3.35	30.32	5.68

[a]Feeder steer price: $36/cwt.; slaughter steer price: $45/cwt.; slaughter heifer price: $44/cwt.

factors, including the feeder steer price, remained invariant. (The feed price is converted to a per bushel corn price, for ease of comparison.)[7/]

The Table shows that as the feed price increases, the allowable feeder heifer price -- which would give equal returns per dollar of cost in feeder steers -- decreases, and the steer-heifer feeder price differential widens.

Appendix C contains the data and method used to calculate the breakeven feeder prices.

It must be noted that the analysis assumes that the producer seeks to maximize return per dollar of cost -- i.e., that capital is the limiting constraint relevant to the decision to purchase either steers or heifers. This analysis merely serves to demonstrate that as the feed price increases, there is a positive pressure upon the feeder sex price differential.

In conclusion, the effect of increasing feed ration prices is to increase the cost of producing a unit weight of slaughter heifer relative to the cost of producing a unit weight of slaughter steer. It is hypothesized, therefore, that the level of feed ration prices, F, is positively associated with the steer-heifer feeder price differential. This hypothesis is based upon the condition that heifers have a higher feed conversion ratio than do steers, and thus, are less feed efficient than are steers. However, it must be noted that producers may respond to changing feed prices by altering feedlot weight gains or substituting ration ingredients, neither of which are accounted for in this analysis.

Sex of Cattle on Feed. There is some indication that the relative quantities of feeder heifers to feeder steers demanded may result from some type of preference on the part of fed cattle producers. Ensminger (p. 1357) suggests that beyond the feed efficiency effect, feeder heifers can be purchased at a lower price per pound than steers because of existing prejudices.

Armstrong, in a general article on cattle and beef, points out that prices may be related to specialization among producers:

> "As feeding and handling characteristics are different for different sexes, this permits feeders to specialize in their operations and permits them to pay higher prices for that sex of animal they prefer to purchase."

Williams and Stout point to differences in these preferences or the tendency to specialize:

> "Numbers of heifers fed depend primarily upon steer-heifer price ratios, but some operators in most areas and most operators in some areas tend to specialize in heifers. A possible reason for this pattern is that the Pacific region and the Central Corn Belt, steers are much preferred to heifers. Feedlot operators in both areas are usually willing to pay sufficiently large premiums for steers to draw these cattle away from other feeding areas."

Gustafson and Van Arsdall point out that in California, the Corn Belt, and the Southern Plains, the proportion of heifers to steers on feed decreases as feedlot size increases; but in Colorado the larger feedlots tend to feed a higher proportion of heifers. Table 2.2 is evidence of regional differences in this proportion.

It is hypothesized that some feedlot operators have a degree of possibly non-economic preference for steers over heifers; and these preferences could result in price premiums which may or may not be related to costs. One measure of this preference is the heifer-steer

Table 2.2. Cattle on Feed, Oct. 1, 1972-1976 Average by Sex for Selected States, 1000 head[a]

	Steers and Steer Calves	Heifers and Heifer Calves	Total[b]	Proportion of Heifers to Steers[c]
Pennsylvania	45.4	4.8	53.6	.105
Ohio	136.2	27.8	165.8	.204
Indiana	118.8	70.0	191.4	.589
Illinois	245.4	144.6	390.0	.589
Iowa	792.6	365.8	1160.0	.462
Nebraska	761.2	451.6	1218.2	.593
Texas	1156.4	632.8	1792.2	.547
Colorado	471.2	337.8	815.6	.717
California	933.0	73.0	1010.6	.078

[a] SOURCE: Cattle on Feed, Quarterly Issues, U.S.D.A., 1972-1976.

[b] Total includes cows and bulls.

[c] Number of heifers on feed divided by the number of steers on feed.

proportion on feed, although, as Williams and Stout suggest this measure may not entirely reflect these preferences since the number of heifers fed partly depends upon steer-heifer price ratios. However, if the heifer-steer proportion on feed depends upon the relative price of feeder steers to heifers one would a priori expect a positive relation between the feeder sex price spread and the heifer-steer proportion on feed. This follows since with an increasing feeder sex price spread, feedlot operators would favor lower priced heifer feeders over steers. On the other hand, if the heifer-steer proportion on feed bears a negative relation to the dependent variable, as the author hypothesizes, then the causation must be from the heifer-steer proportion to the feeder sex price spread.

The Supply Variables

Backgrounding Costs. Previously it was noted that since steers make larger gains on nonfattening feeds they are usually preferred to heifers for wintering; and that steers are generally more feed efficient than heifers of approximately equal age and weight.[8/] Under these assumptions, it is hypothesized that given an increase in the price of feed for a backgrounding program,[9/] farmers will increase their marketings of heifers relative to steers at a given weight and age -- resulting in a lower offer price for heifers relative to steers in the short run (one year). In essence, from the farmer's viewpoint, it is more desirable to hold steers rather than heifers if feed supplies are limited, or if feed prices are high.

<u>Price Expectations</u>. Keith and Purcell conclude that as cattle prices increase, steers and heifers are held for longer periods in anticipation of even higher prices; similarly, as cattle prices decline, steers and heifers are held for shorter periods. In analyzing feeder sex price spreads, the concern is with marketings of heifers relative to steers of a given weight and age, at a given point in time. Actually, cow-calf men may face three alternatives: sell weaned calves at approximately 6-7 months; sell yearlings from 9 months of age; or sell long yearlings at up to 16 months of age. As prices increase farmers will (under the assumptions set forth) opt to market fewer calves, and subsequently, more yearlings. But since steers gain faster, reaching higher weights before heifers of equal age, the relative quantity of heifers to steers marketed in the lower weight classes will increase. Thus, for 6-7 month steer and heifer calves at 400-500 lbs., the relative quantity of heifers to steers marketed will increase under conditions of increasing prices.

In the long run a different result might be expected. If farmers expect long run price increases (i.e., for more than one or two years hence), they may retain more heifers for breeding rather than adjust culling rates of brood cowherds; this would have the effect of increasing proportion of steers to heifers marketed, and thus decrease the steer-heifer feeder price differential. This model concentrates upon expected short run changes rather than expected long run changes, and hence captures the former positive impact of price expectations on the feeder sex price differential.

Thus, it is hypothesized that, in the short run (one year), anticipation of higher prices will cause an increase in the steer-heifer feeder price differential for cattle of a given age and weight; and short run anticipation of lower prices will cause the feeder sex price differential to decline.

A Cross-Section Model Over Time

As noted in the first chapter, this study focuses upon the identification of steer-heifer price relationships over market regions in the U.S. as well as over time. Thus, a cross-sectional time-series model is specified.

However in many cases feeder cattle are shipped long distances to feedlots, and it becomes necessary to observe the demand variables in cattle feeding regions and the supply variables in the regions where the feeder cattle were produced. In the following, regions where cattle are primarily fattened for slaughter on high energy rations are referred to as feeding regions, and regions where cattle are primarily backgrounded for sale to feedlots are referred to as stocking regions. According to the geographic origin of feeder cattle shipped to feedlots, specific feeding regions correspond with specific stocking regions.

For the purpose of explaining changes in the steer-heifer price differential (Y_{it}) in the i^{th} stocking region during the t^{th} time period, the following theoretical cross-section time-series model is specified where the subscript i represents an observation on a supply variable in a stocking region, and the subscript i' represents an observation on a demand variable in a feeding region:

$$Y_{it} = f(X_{1,it}, X_{2,it}, X_{3,i't}, X_{4,i't}, X_{5,i't})$$

where

Y_{it} = steer-heifer feeder price differential;

$X_{1,it}$ = a measure of backgrounding costs;

$X_{2,it}$ = a measure of price expectations;

$X_{3,i't}$ = a measure of the steer-heifer fed cattle price differential;

$X_{4,i't}$ = a measure of feedlot feed prices in finishing cattle for slaughter;

$X_{5,i't}$ = a measure of the tendency of feedlot operators to specialize in either steers or heifers, or to prefer one sex over the other.

Over time, an observation on the dependent and supply variables in the i^{th} stocking region corresponds with an observation in the i'^{th} feeding region, which services the i^{th} stocking region.

1/ Some studies have shown heifers to be more feed efficient than steers, under experimental conditions (Harpster, et. al. and Ritchie, et. al.). However it is generally considered that, under actual conditions, steers exhibit lower feed conversion ratios than do heifers.

2/ A price differential between steer and heifer carcasses may arise since processing costs may differ between steer and heifer beef.

3/ In this analysis, the derived demand is treated as the demand for feeder steers and heifers, beyond the backgrounding stage at the point of feedlot purchase, which is probably at the yearling age; but since (in Chapter III) on the supply side, this analysis concentrates on the weaned calf supply, it is taken for granted that the demand factors which affect the steer-heifer feeder calf price spread are passed down through the market for stocker animals.

4/ Operationally, the market is defined as the three month supply (Sept.-Oct.-Nov.) of 400-500 lb. steers and heifers at weaning age for each year (as is further discussed in Chapter III).

5/ The short run is defined here as a three month period from September to November.

6/ Subtracting (2.12) from (2.13):

$$FCh - FCs = (FCRh * F) - (FCRs * F)$$

7/ The method of converting per cwt. feed prices to per bushel corn prices is to correlate the two. The data are published in Livestock and Meat Situation, "Corn Belt Cattle Feeding". With a correlation coefficient of .89, the estimated relationship is:

$$P_{feed} = .98 * P_{corn} + 2.712$$

where:

P_{feed} = dollar per cwt. price for all feed, as fed.

P_{corn} = dollar per bushel corn price.

For this estimate, the range in corn price was approximately from 0.95 to 3.50.

8/ However, as the animals progress from the weaned calf stage, the weight differential widens between steers and heifers of equal age.

9/ Backgrounding is defined as growing or maintaining cattle on low energy, high roughage rations.

CHAPTER III

PROCEDURES

The research procedures undertaken in obtaining secondary data are outlined in this chapter. First, the time period and cross-sectional units are discussed, including assumed feeder cattle transportation patterns. Second, all variables are defined operationally.

Time Period

The years 1964 through 1976 were chosen for analysis. This period seems current enough to apply to present conditions, provides an ample data base, and includes at least one complete cattle cycle. Prior to 1964, data for some regions was unavailable.

Areas

The operational model outlined previously requires delineation of a set of geographic regions according to stocking and feeding activities. The model futher requires that transportation patterns from stocking to feeding regions be specified since any stocking region, where the dependent variable is observed, must correspond to it's relevant feeding region, where the demand variables are observed. Hence the correspondence between the dependent variable and the demand variables is based upon assumed feeder cattle movements to feedlots.

Precise data on the transportation of cattle and calves to feedlots are not presently available; however, information gathered from interviews and current literature allow some approximate conclusions, at least for the regions examined in this study. Although the conclusions presented are at best adequate and at worst somewhat arbitrary, they are based upon the only sources of evidence available to the author's knowledge.

Six stocking regions and five feeding regions are specified in Tables 3.1 and 3.2, along with representative market points for data purposes. Because it was impossible to weight the regional data by state, in most cases each region is represented by one state and one market point.[1/] Geographic boundaries are loosely drawn, and since each region is represented in most cases by only one state the reader may follow a different interpretation of the regional demarcations.

A report prepared in 1964 under contract for the Agricultural Research Service (Kearney) notes that feedlots in the Mountain states (Colorado, Utah and Wyoming) use mainly locally produced cattle, while Ohio feedlots use mainly eastern and southeastern cattle. In 1970 Gustafson and Van Arsdall reported that southeastern feeder cattle move to the Plains (Oklahoma, Texas) in large numbers since mixed breeds, characteristic of Southeastern cattle, appear more acceptable to Plains feedlots than to Western Corn Belt feedlots. The authors conclude, however, that the present flow of feeder cattle has changed slowly over time due to the development of the interstate highway network, shifts in population centers, and development of new sources of feeder cattle in the Southeast and Corn Belt.

Shipping patterns are discussed for each stocking region (Table 3.1) and feeding region (Table 3.2).

Table 3.1. Stocking Regions

Stocking Region	Representative State	Representative Market
Virginia	Virginia	Statewide
Southeast[a]	Georgia	Thomasville
Western Corn Belt[b]	Illinois	Springfield
Plains[c]	Oklahoma	Oklahoma City
Mountains[d]	Colorado	Greely
California	California	San Francisco

a/ Includes: Georgia, North Carolina, South Carolina, and Florida.

b/ Includes: Iowa, Illinois, and Indiana.

c/ Includes: Oklahoma and Texas

d/ Includes: Colorado, Wyoming, and Utah.

Table 3.2. Feeding Regions

Feeding Region	Representative State(s)	Representative Market
Northeast[a/]	Ohio, Pennsylvania	Lancaster
Plains	Oklahoma, Texas	Oklahoma City
Western Corn Belt	Illinois	Springfield
Mountains	Colorado	Greely
California	California	San Francisco

[a/] Includes Ohio, Pennsylvania, New York, Maryland, Delaware and other Northeastern states; other feeding regions are defined similar to the stocking regions in Table 3.1.

Virginia

Primarily a cow-calf producing state, Virginia fattens relatively few cattle, and most feeders are shipped to feedlots out of state. At least two reactive programming studies (Dietrich), (Liu and West) have identified Pennsylvania and Ohio as optimum destination points, although studies of this nature are not intended as precise descriptions of prevailing conditions.

For purposes of the operational model, two-thirds of Virginia's cattle were assumed to move into Pennsylvania, and one-third to Ohio.[2/] Presently, lack of precise data precludes a more detailed estimate of Virginia outshipments.

Georgia

As is typical of the Southeastern states, most Georgia feeders move to out-of-state feedlots. Inshipment data, collected by the Statistical Reporting Service for five major feeding states (Iowa, Nebraska, Texas, Colorado, California), provide some indication of the direction of flow from the Southeast. This data is summarized in Table 3.3.

While the estimates in Table 3.3 include all cattle (stocker, feeder, fat), and although the estimates are limited to only five inshipment states for a three year time span, it appears that movement from the Southeast into the Midwest, California and Colorado is minor compared to shipments from the Southeast into Texas. Thus, it is assumed that fed cattle production conditions in the Plains feeding region govern the derived demand relation for Georgia feeder cattle.

Table 3.3. Outshipments From the Southeast to Five Major Feeding States -- as a Percent of Total Outshipments[a]

Destination	Origin/Southeast[b]
Iowa	1
Nebraska	1
Colorado	-
California	-
Texas	98

[a]Estimates include all cattle (stocker, feeder, fat) and calves; average for 1970-1972; cattle outshipment data refer only to the five destination states.

[b]Southeast includes: Georgia, North Carolina, South Carolina, and Florida.

SOURCE: Boles, et. al.

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Illinois

Since the Corn Belt is a major fed cattle producer, it is unlikely that feeder cattle sold in this region move long distances to feedlots. Indeed, most feeders sold in Illinois are probably fattened in-state. Gustafson and Van Arsdall report no significant movement of feeder cattle from the Corn Belt states to either Oklahoma, Texas, Colorado
13 or California.

Colorado and California

As major fed cattle producing states, Colorado, and more notably California, must import feeders from other states. Gustafson and Van Arsdall report no significant movement of feeder cattle out of these two states -- suggesting that most of the feeders sold are fattened in-state. In addition, imports of stocker and feeder cattle into Colorado have historically represented a large proportion of fed-cattle marketings in the state (Colorado Department of Agriculture). Hence, for purposes of the operational model, Colorado and California feeder cattle are assumed to remain in-state.

Oklahoma

Feeder cattle produced in the Southeast move to the Plains in large numbers, while some of the Plains cattle move elsewhere for fattening. Probably between 60 to 70 percent of the feeder cattle sold in Oklahoma remain in-state.[3/] The remaining 30 to 40 percent are shipped mostly to Texas, Colorado, California and the Corn Belt (Gustafson and Van Arsdall). The relative proportions going to each of the latter destinations, however, is unclear. Thus, although it is recognized that many feeder cattle marketed in Oklahoma are shipped out-of-state, it is assumed that fed cattle production conditions in Oklahoma govern the derived demand relation for Oklahoma feeders; and, for purposes of the operational model, Oklahoma feeder cattle are assumed to remain in-state.

Summary

Based on the evidence presented above, Table 3.4 summarizes feeder cattle movements from each of the six stocking regions (in Table 3.1) to each of the five feeding regions (in Table 3.2).

Shipments from the Southeast were equally divided between Texas and Oklahoma (Plains). Shipments from Virginia were assumed to move into Pennsylvania and Ohio (Northeast) in a 2:1 proportion, (65% to Pennsylvania and 35% to Ohio). Numbers in the table represent the proportions of feeders sold in the stocking regions to the respective feeding regions and should sum horizontally to 1.0.

Operational Variable Definitions

The Dependent Variables

The steer-heifer feeder price spread in the i^{th} stocking region during the t^{th} year is specified as the dependent variable. The variable may be defined operationally as a price differential (the steer price minus the heifer price) or as a price ratio (the steer price divided by the heifer price). The two measures are not equivalent, for when the price differential is increasing the price ratio may actually remain constant or diminish, and vice-versa. For example, if both increase by the same percentage the ratio remains unchanged while the differential increases. More concretely, if the steer price increased from 30 to 50

Table 3.4. Summary of Feeder Cattle Movements for the Operational Model[a]

Stocking Region/Source	Feeding Region/Destination: Northeast Pa.	Northeast Ohio	Plains[b] Okla.	Plains[b] Texas	W. Corn Belt	Mountains	California
Virginia	0.65	0.35					
Southeast			0.5	0.5			
Western Corn Belt					1.0		
Plains[b]			1.0				
Mountains						1.0	
California							1.0

[a]This Table is intended for use in the operational model only and does not purport to precisely depict actual conditions.

[b]From Tables 3.1 and 3.2, the Plains stocking region is represented by Oklahoma alone, while the Plains feeding region is represented by both Oklahoma and Texas. As previously discussed, Oklahoma feeders were assumed to remain in-state and Southeastern cattle were assumed to be shipped to Oklahoma and Texas in equal proportions.

while the heifer price increased from 27 to 46, the price differential would increase from 3 to 4 while the price ratio would decline from 1.11 to 1.08.

In the operational model, both measures could be tested empirically. In most literature, however, the convention is to use a differential rather than a ratio as an interpretation of relative value. This convention is followed in the operational model.[4/]

Of additional importance to the operational specification is the choice of a weight and age class for the animals. Heifers generally mature earlier and are slaughtered at lighter weights than steers. Also heifers are generally lighter than steers of equal age -- so in any weight class one might expect the average heifer wieght to be smaller than the average steer weight. Since price is a function of both weight and age, these factors must be either held constant or accounted for to avoid unexplained changes in the sex price spread due to changes in selling weight or age.

With respect to age, feeder steers and heifers have traditionally been classified (and are so classified in the data sources) as either calves or yearlings. Calves are usually sold as animals between 6 to 9 months of age. Yearlings, on the other hand, may range in age from short yearlings (11 months) to long yearlings (16 months), (Arsdall and Skold). Thus, within age classes, the range in calf age is less than the range in yearling age -- suggesting less price variation, due to age alone, among calves than among yearlings.

Also, over the cattle cycle, culling rates of heifer herds may vary, which would influence the sex price spread from one year to the next. Since a herd of heifer calves is less likely than a herd of heifer yearlings to have been culled for replacement stock (Neumann and Snapp, p. 170), the effect of year to year culling rate changes upon the sex price spread is less with calves than with yearlings.

Thus, calves were specified, rather than yearlings, in operationally defining the dependent variable.

With respect to weight, steer and heifer calf prices are reported in increments of 100 lbs. in most markets. As calves are either sold close to weaning or held over for sale as yearlings, it seems appropriate to designate the weaning weight class in operationally defining the dependent variable. Table 3.5 summarizes estimated median beef steer calf weights at 205 days (6-7 months) in various states in 1970 and 1975. For the most part, median steer weights were in the 400-500 lb. weight class.

The class of 400-500 lb. feeder calves was chosen in operationally defining the dependent variable -- a class that approximates the weaning weight for steers and heifers. Although weaned heifers may weigh somewhat less than weaned steers, it is necessary only to hold weight constant since changes in weight can change prices.

One final complication encountered in developing the operational dependent variable was that, in most markets, feeder prices are available for the fall season only. Thus, price observations were confined to annual unweighted three month averages (Sept.-Oct.-Nov.).

The steer-heifer price differential, D_{it}, is defined operationally for the i^{th} stocker region during the t^{th} year as:

(3.1) $$D_{it} = Pfs_{it} - Pfh_{it}$$

Table 3.5. Estimates of Median Steer Calf Weights at 205 Days, 1970 and 1975

	1970	1975[b/]
Ohio	420	442
Illinois	435	452
Virginia	450	490
North Carolina	402	425
Georgia	400	437
Albama	380	425
Oklahoma[a/]	440	462
Texas	425	445
Arizona	403	403

[a/]Weights in the Southwest (Oklahoma, Texas, Arizona) were for beef calves at time of sale, not necessarily at 205 days.

[b/]Projected estimates.

SOURCE: Arsdall and Skold.

where:

Pfs_{it} = Fall season price per cwt. (unweighted Sept.-Oct.-Nov. average) of a choice, 400-500 lb. feeder steer[5/] in the i^{th} stocking region during the t^{th} year.

Pfh_{it} = Fall season price per cwt. (unweighted Sept.-Oct.-Nov. average) of a choice 400-500 lb. feeder heifer[6/] in the i^{th} stocking region during the t^{th} year.

Feeder cattle price data were obtained from the Agricultural Marketing Service (USDA) and the Animal Science Department Staff of the Extension Division, Virginia Polytechnic Institute and State University.

The Supply Variables

Backgrounding Costs: Blakely has identified the price of hay, a major feed component of most growing rations, as one measure of backgrounding costs. He found the measure, however, to be insignificant in forecasting feeder steer prices.[7/] Perhaps one reason for this result is that hay becomes an input both to the supply and the derived demand relation for feeder cattle; on the supply side the hay price is positively related to the feeder price and on the demand side negatively related.[8/] Thus a change in the hay price may, on balance, have a negligible effect upon feeder steer prices.

The result does not necessarily mean, however, that hay prices -- as a measure of backgrounding costs -- will have no effect upon the steer-heifer feeder price spread. From the theoretical development of feed costs for steers and heifers in Chapter II, an increase in hay prices is hypothesized to increase sale offerings of heifers relative to steers -- with a reinforcing positive pressure on the differential from the demand side.

Hay prices, $PHAY_{it}$, are defined operationally in the i^{th} stocking region during the t^{th} year as:

(3.2) $PHAY_{it}$ = annual average price, in dollars per ton, of all hay in the i^{th} stocker region during the t^{th} year (weighted monthly by average tons sold).

Hay prices are reported annually in Agricultural Prices, Economic Research Service, U.S.D.A.

Price Expectations: The relationship between current and historical prices for feeder steers (or the rate of price change) formed the basis of the price expectation variable, Pe_{it}. Keith and Purcell, on the basis of 1974 questionnaire results, concluded that most cow-calf men are reluctant to admit that their own collective decisions are largely responsible for the level of cattle prices; that cattlemen do seem to form their opinion about future cattle prices primarily on the basis of prices for the past 1-2 years; and that rapidly climbing (or falling) prices lead to a general consensus of higher (or lower) prices for the future.

The difference between current and three-previous-year average steer calf prices is one measure of price expectations which farmers may use. The selection of a 3-year lag period is admittedly arbitrary; however, a period less than two years would not accurately reflect a definite historical price basis, and a lag period much longer than three years is inconsistent with the conclusions of Keith and Purcell.

Price expectations, Pe_{it}, are defined operationally for the i^{th} stocking region during the t^{th} year as:

$$(3.3) \quad Pe_{it} = Pfs_{it} - \frac{(Pfs_{i,t-1} + Pfs_{i,t-2} + Pfs_{i,t-3})}{3}$$

where:

Pfs_{it} = Fall season price, in dollars per cwt., of a choice, 400-500 lb. feeder steer in the i^{th} stocking region during the (t, ..., t-3) year.

Price data were obtained from the Agricultural Marketing Service and the Animal Science Department Staff of the Extension Division, Virginia Polytechnic Institute and State University.

The Demand Variables

Fed Cattle Sex Price Spread: This variable, $FED_{i't}$,[9] is defined operationally in the i'^{th} feeding region during the t^{th} year as:

$$(3.4) \quad FED_{i't} = PFs_{i't} - PFh_{i't}$$

where:

$PFs_{i't}$ = Fall season price, in dollars per cwt., of a choice, 1100-1300 lb. slaughter steer in the i'^{th} feeding region during the t^{th} year (unweighted Sept.-Oct.-Nov. average).

$PFh_{i't}$ = Fall season price, in dollars per cwt., of a choice, 900-1100 lb. slaughter heifer in the i'^{th} feeding region during the t^{th} year.

A lower weight class is specified for heifers since heifers are slaughtered at lower weights than are steers; hence, prices observed in this group would be drawn from a more representative sample. Average liveweights of choice slaughter steers and heifers marketed in 1968 at 15 specified markets were 1124 and 935 respectively (Gustafson and Van Arsdall).

Inclusion of spring fed cattle prices would probably provide a more representative sample -- and thus more accurately reflect the impact of fed cattle prices upon feeder cattle prices. However, for many markets, only fall price quotations were available.

Monthly fed cattle price quotations were obtained directly from the Agricultural Marketing Service, USDA.

Feed Prices: In order to reflect true feed cost differences among each of the i'th feeding regions as well as across time, it would be necessary to develop a typical feed ration for each feeding region and from this ration construct an index of feed prices per unit weight of feed.

Gustafson and Van Arsdall report that barley and sorghum increase their importance as ration components as one moves from the Corn Belt to the Western states. Estimation of typical rations by feeding region proved difficult, however, since the composition of rations even within regions varies according to relative grain prices and the types of feed produced locally.

Thus, since corn grain and corn silage represent a major component of most feeding rations, the price of corn grain is specified as the operational feed price variable.[10/] It is recognized that actual feed prices -- based upon rations fed -- may be at variance with corn grain prices; but since all feed grains are regarded as close substitute commodities, the corn price may serve as a close proxy for other feed prices.[11/]

The price of feed in the i'^{th} feeding region during the t^{th} year, $CRN_{i't}$, is defined operationally as:

(3.5) $CRN_{i't}$ = annual per bushel price received by farmers for all corn grain, weighted by grade and monthly volume sold, in the i'^{th} feeding region during the t^{th} year.

Price data were obtained from annual issues of Agricultural Prices, Economic Research Service, U.S.D.A.

Heifers On Feed: The annual average proportion of heifers to steers on feed was calculated for each feeding region by summing quarterly estimates of heifers on feed and dividing this by the sum of quarterly estimates of steers on feed. The annual proportion, $HOF_{i't}$, of heifers to steers on feed in the i'^{th} feeding region during the t^{th} year is defined operationally as:

$$(3.6) \quad HOF_{i't} = (HI_{i't} + HII_{i't} + HIII_{i't} + HIV_{i't})/(SI_{i't} + SII_{i't} + SIII_{i't} + SIV_{i't})$$

where:

$HI_{i't}, \ldots, HIV_{i't}$ = quarterly estimate of heifers on feed in the i'^{th} feeding region during the t^{th} year.

$SI_{i't}, \ldots, SIV_{i't}$ = quarterly estimate of steers on feed in the i'^{th} feeding region during the t^{th} year.

Data were obtained from quarterly issues of Cattle on Feed, U.S.D.A.

Zero-one Variables

Regional intercept shifter variables, with Virginia as the omitted region, were included in the model to test among stocking regions for significant differences in the dependent variable means and for significant differences in the residual means, after inclusion of the economic variables.

In addition, subjective experimentation with some zero-one slope shifters suggested that coefficient estimates for some variables may differ among cross-sectional units.

Table 3.6 summarizes the operational specification of each variable: it's theoretical specification; it's operational definition; it's location of observation (stocking or feeding region); it's time of observation; and finally it's secondary data source.

1/ A subjective weighting was possible within the Northeast region, thus, two representative states characterized the Northeast feeding region.

2/ Based upon personal correspondences with K. C. Williamson, Department of Animal Science, Virginia Polytechnic Institute and State University and Reggie B. Reynolds, Executive Secretary, Virginia Beef Cattle Association, Daleville, Virginia.

3/ Based upon personal correspondence with Wayne D. Purcell, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma.

4/ The magnitude of the differential over time might be affected by the absolute price level, in which case a ratio would more accurately measure relative prices. But, in the economic model, the measure to which buyers and sellers respond (the differential) is the measure which more accurately reflects changing economic forces.

5/ 300-500 lb. feeder steer before 1972.

6/ 300-500 lb. feeder heifer before 1972.

7/ The supply-demand relation, in this context, is from feeder to fed cattle markets.

8/ In the short run, however, higher backrounding costs may stimulate feeder sales, lowering the price.

9/ With each i^{th} cross-sectional stocking region unit, there is uniquely associated an i'^{th} cross-sectional feeding region unit based upon assumed feeder movements from stocking region i to feeding region i'.

10/ To some extent, corn grain and corn silage could be considered interchangable as feeds since U.S.D.A.'s Livestock and Meat Situation considers one ton of silage equivalent to 5 bushels of corn plus 330 lbs. of hay.

11/ Sorghum, barley and wheat prices were entered as independent variables in addition to corn but failed to contribute to any explanation of the dependent variable.

Table 3.6. Summary of Operational Variables

Characteristic	Dependent Variable	- - - - - - - - - - - Independent Variables	- - - - - - - - - - -	
Theoretical specification	Steer-heifer feeder price spread, D_{it}	Backgrounding costs, $PHAY_{it}$	Price expectations, Pe_{it}	Steer-heifer fed cattle price spread $FED_{i't}$
Operational definition	Price differential ($/cwt.) between 400-500 lb. choice steer and heifer calves	Price ($/ton) of all hay	Current (t) fall feeder steer calf price minus moving average of previous three years prices, ($/cwt.)	Price differential between choice 1100-1300 lb. slaughter steers and 900-1100 lb. choice slaughter heifers ($/cwt.)
Region of observation	Stocking region, i	Stocking region, i	Stocking region, i	Feeding region, i'
Time of observation	Year t, unweighted Sept.-Oct.-Nov. average	Year t, annual average weighted by tons sold	Year t, t-1, t-2, t-3; unweighted Sept.-Oct.-Nov. average	Year t, unweighted Sept.-Oct.-Nov. average
Data source	Agric. Marketing Service, USDA; Extension Div., VPI & SU	Agricultural Prices, USDA	Agricultural Marketing Service, USDA; Extension Div., VPI & SU	Agricultural Marketing Service, USDA

Table 3.6. Continued

Characteristic	Independent Variables			
Theoretical specification	Preferences of feedlot owners, $HOF_{i't}$	Feed prices, $CRN_{i't}$	Test for significant intercept differences among cross-sectional units	Test for significant slope differences for each exogeneous variable among cross-sectional units
Operational definition	Proportion of heifers to steers on feed	Price per bushel of corn grain weighted by grade and monthly volume sold	Zero-one stocking region identifier	Zero-one stocking region identifier
Region of observation	Feeding region, i'	Feeding region, i'	Stocking region, i	Stocking region i
Time of observation	Year t, Jan., April, July, Oct.	Year t, annual average		
Data source	Cattle on Feed, USDA	Agricultural Prices, USDA		

CHAPTER IV

EMPIRICAL ANALYSIS

In this chapter a statistical model is developed to estimate the theoretically hypothesized relationships discussed in Chapter II. Alternative estimation procedures are first discussed and then the results of the analysis are presented.

Problems of Estimation

The theoretical model in Chapter II was transformed into a statistical model to measure the influence of each independent variable upon the dependent variable.

The statistical model, in general linear form, is summarized functionally below. Zero-one regional intercept shifters were included, resulting in the addition to the theoretical model of five variables representing each of the six stocking regions.

$$(4.1)\quad Y_{it} = B_0 + B_1X_{1,it} + B_2X_{2,it} + B_3X_{3,i't} + B_4X_{4,i't} + B_5X_{5,i't} + B_6R_{1,i} + B_7R_{2,i} + B_8R_{3,i} + B_9R_{4,i} + B_{10}R_{5,i} + e_{it}$$

where:

Y = the dependent variable.

X_1, X_2 = the independent supply variables.

X_3, X_4, X_5 = the independent demand variables.

B's = the true parameters associated with each of the 10 independent variables (including the intercept, B_0).

$R_1, \ldots, R_5$ = stocking region zero-one intercept shifters for each of the stocking regions.

e_{it} = the stochastic error term corresponding to each observation on the dependent variable.

t = (1, ..., 13) = annual time subscript.

i = (1, ..., 6) = stocking region subscripts associated with the supply variables.

i' = (1', ..., 5') = feeding region subscripts associated with the demand variables; each i uniquely corresponds to an i' in each observation based upon assumed cattle movements from feeding to stocking regions.

Use of the i and i' subscripts may be demonstrated as follows: let i = 1 and i' = 1'; further, let 1 denote the Virginia stocking region (Table 3.1) and let 1' denote the Northeast feeding region (Table 3.2). We have, for one observation on the dependent variable:

$$(4.2) \quad Y_{1t} = B_0 + \ldots + B_2X_{2,1t} + \ldots + B_4X_{4,1't} + \ldots + e_{1t}$$

where, as previously stated, X_2 is a supply (stocking region) variable and X_4 is a demand (feeding region) variable. The subscript 1 coincides with the subscript 1' in the same way that the Virginia stocking region coincides with the Northeast feeding region -- by virtue of the assumption that Virginia cattle are destined for the Northeast feeding region (from Table 3.4).1/

Pooled Time-Series Cross-Section Data

The time-series cross-section model represented by (4.1) requires statistical assumptions that vary according to alternative estimation techniques. To provide a general framework for discussion of alternative techniques, the model is specified under the following conditions:

(4.3) $E(e_{it}) = 0$ for all i and t

(4.4) No exact linear relation exists between any two explanatory variables.

Aside from these assumptions, the behavior of the disturbances is of particular importance to pooled time-series cross-section observations. In addition to conditions (4.3) and (4.4), the classical OLS regression model assumes homoskedasticity and the absence of serial correlation:

(4.5) $E(e_{it}^2) = \sigma^2$

(4.6) $E(e_{it}e_{h\mu}) = 0$ where h and μ are alternative region, time indicators; $i \neq h$ and $t \neq \mu$.

If the disturbances are not homoskedastic, the least squares estimators do not have the smallest variance in a class of unbiased estimators, and therefore, they are not efficient (Kmenta, p. 252). The same result obtains if the disturbances are autoregressive -- namely, the loss of efficiency.

There may be reason to suspect that the behavior of the disturbances over cross-sectional units is different from their behavior over time. Concerning time-series data, one may suspect that the disturbances are autoregressive (in violation of (4.6)); concerning cross-sectional data, one might suspect that the disturbances are heteroskedastic (in violation of (4.5)). Thus, with pooled time-series cross-section observations there is a danger of violating two central assumptions of the OLS estimator.

An approach by Parks explicitly addresses these two problems. The model assumes a first order autoregressive scheme over time, unequal error variances among cross-sectional units, and mutual dependence of the disturbances among cross-sectional units. The procedure gives asymptotically efficient estimates of the coefficients under these three assumptions.

The specification of the disturbances is given by:

(4.7) $$E(e_{it}^2) = \sigma_i^2 \text{ (all i,t)}$$

(4.8) $$e_{it} = P_i e_{i,t-1} + u_{it} \text{ (all i)}$$

(4.9) $$E(e_{it} e_{ht}) = \sigma_{ih} \text{ (all t, } i \neq h)$$

where:

σ_i^2 = the variance of the disturbance in the i^{th} region for any t.

P_i = the first order autocorrelation coefficient in the i^{th} region across time.

u_{it} = nonautoregressive and homoskedastic disturbance.

σ_{ih} = the covariance of the distrubances between the i^{th} and h^{th} cross-sectional units in the t^{th} time period.

Assumption (4.7) presupposes a different variance of the disturbances for each of the i regions; (4.8) assumes that the disturbances are autoregressive across time for any region, i; and (4.9) assumes a different covariance for the disturbance between any two regions for all t.

Note that the value of the parameter, P, is allowed to vary from one cross-sectional unit to another. Thus, separate first order autocorrelation coefficients are computed for each region over time. Further, by (4.9), the disturbances in different cross sections for all time periods are correlated.

The Parks transformation procedure is explained briefly here, but for a more extensive explanation, see (Kmenta, pp. 512-514) or (Parks).[2/]

Unbiased and asymptotically efficient parameter estimates are obtained by: (1) estimating the OLS parameters and then estimating P_i for each cross-sectional unit from the OLS residuals; (2) transforming each variable by a simple formula using P_i to obtain new variables; (3) re-estimate by OLS to obtain new residuals; (4) from the new residuals obtain asymptotically efficient estimates of the error variance-covariance matrix (a new omega matrix); with Aitken's GLS estimation procedure, estimating asymptotically efficient regression coefficients using the transformed omega matrix.

Another approach to this problem by Fuller and Battese assumes that the disturbance term has a cross-sectional, a time series and a random component. Khu decomposes the error term into a constant regional effect and a random effect. However the Parks method explicitely combines the assumption frequently made about cross-sectional observations (heteroskedosticity) with the assumption made frequently about time series observations (autoregression). One measure of the degree to which these assumptions are violated is by comparing the OLS estimates with the Parks estimates.

Parameter estimates of (4.1) were obtained using both the OLS and the Parks method estimates. Under the OLS assumptions, parameter estimates are unbiased and have the smallest variance; under the Parks assumptions, parameter estimates are unbiased and asymptotically efficient.

Problems with Multicollinearity

Multicollinearity is a question of degree, not of kind. Thus, the only requirement in a statistical model is the absence of perfect multicollinearity, a condition ruled out by assumption (4.4). However, the presence of a high degree of multicollinearity can present estimation as well as interpretation problems.

Estimation problems may arise because a high degree of multicollinearity can lead to large coefficient variances and thus untrustworthy parameter estimates.

Interpretation problems may arise if, in the presence of a high degree of multicollinearity, the inclusion of an exogeneous variable highly collinear with a currently used exogeneous variable may affect the value of both parameter estimates. Consequently the magnitudes of the estimates are highly dependent upon the model specification, especially, as with the present model, if more than a few zero-one variables are specified.

Intercept and Slope Shifters

The statistical model (4.1) contains a set of zero-one intercept shifters. The purpose here is to contrast the model with intercept shifters and exogeneous variables to another model containing only intercept shifters -- thereby providing one measure of how well the exogeneous variables explain regional variation in the dependent variable. This measure could be obtained more directly by estimating a separate model for each region. (Also, by definition, estimation of separate models would remove the heteroskedasticity problem over region.)

However, given the limited volume of current data, it seems impractical to estimate separate regional models. Inclusion of zero-one variables amounts to fitting a separate regression equation for each region; in addition, the procedure provides a means of testing for significant intercept and slope differences among regions.

Results of Analysis

The remaining part of this chapter contains the statistical results and economic analysis in order to: (1) identify and interpret the major factors which influence the steer-heifer price differential; and (2) provide some basis for judging any divergence between the actual sex price differential and the "perfect" market sex price differential. In addition, mean values of the dependent and exogeneous variables are presented by region in order to more clearly delineate their inter-regional variation. These results help to indicate which variables in the model contribute to regional (as opposed to temporal) variation in the steer-heifer price differential.

Mean Differences in the Variables by Region

To more clearly delineate their significance, mean values for each of the variables were calculated by region. Since Virginia is the primary focus of this analysis, the null hypothesis tested is: the mean value of each variable in the Virginia region equals its mean value for each of the other five stocking regions. The magnitudes of all variables may indicate differences among the five remaining regions, but only their differences from Virginia values were tested statistically.

The means and their standard deviations are contained in Table 4.1, and were calculated directly from the data. Probability levels (P_r) for the test of hypothesis were determined with OLS regression analysis by regressing each variable against zero-one intercept shifters, with Virginia as the omitted region.

The results of this analysis indicate that the sex price spread for feeder calves in Virginia is statistically greater than the sex price spread in the other five regions. The remaining variables will be discussed subsequently.

The Estimated Models

Parameter estimates were obtained from three equations: a regression of the dependent variable upon (1) the regional zero-one intercept shifters alone by OLS; (2) the regional intercept shifters and the economic exogeneous variables, the OLS method; and (3) the regional intercept shifters and the economic exogeneous variables by the Parks method. With exception of one explanatory variable, the fed cattle sex price differential, the Parks method coefficient estimates did not appear to

Table 4.1. Estimated Mean Values of the Variables, by Region

	Mean	Standard Deviation	Pr[a/]
The Steer-Heifer Price Differential ($/cwt.)			
Virginia	7.76	1.77	--
California	5.95	2.37	.0326
Corn Belt	4.20	1.47	.0001
Mountains	4.63	1.86	.0002
Southeast	4.57	2.13	.0001
Plains	6.13	2.41	.0436
All Regions	5.54	2.30	--
Price of Hay (PHAY) ($/ton)			
Virginia	39.2	7.64	--
California	41.1	17.47	.6842
Corn Belt	29.5	10.06	.0318
Mountains	35.3	12.20	.3800
Southeast	33.2	7.65	.1725
Plains	31.33	10.82	.0790
All Regions	34.93	11.51	--
Rate of Annual Price Change (Pe) ($/cwt.)			
Virginia	1.2	9.81	--
California	1.0	10.05	.9647
Corn Belt	1.3	9.28	.9711
Mountains	.8	11.23	.9173
Southeast	1.0	10.02	.9617
Plains	1.3	10.29	.9783
All Regions	1.1	9.67	--
Fed Cattle Price Differential (FED) ($/cwt.)			
Virginia (Pa., Ohio)[b/]	2.61	1.79	--
California (California)	1.36	.55	.001
Corn Belt (Corn Belt)	1.64	.84	.007
Mountains (Mountains)	1.29	.48	.0004

Table 4.1. Continued

	Mean	Standard Deviation	Pr
Southeast (Plains)	1.19	.31	.0001
Plains (Plains)	1.16	.35	.0001
All Regions	1.54	.99	--
Price of Corn (CRN) ($/bu.)			
Virginia (Pa., Ohio)	1.71	.64	--
California (California)	2.10	.86	.1854
Corn Belt (Corn Belt)	1.61	.69	.7294
Mountains (Mountains)	1.74	.60	.9174
Southeast (Plains)	1.73	.70	.9428
Plains (Plains)	1.72	.72	.9838
All Regions	1.77	.68	--
Proportion of Heifers to Steers on Feed (HOF) (Ratio)			
Virginia (Pa., Ohio)	.141	.031	--
California (California)	.079	.021	.4407
Corn Belt (Corn Belt)	.488	.108	.0001
Mountains (Mountains)	.716	.113	.0001
Southeast (Southeast)	.774	.296	.0001
Plains (Plains)	.740	.332	.0001
All Regions	.490	.34	--

[a/] The probability that the value of the mean is equal to the value of the mean for Virginia.

[b/] Feeding regions for the respective stocking regions are enclosed in parentheses. For the three demand variables (FED, CRN, HOF), the estimated means pertain to the values in the feeding regions.

differ substantially from the OLS coefficient estimates. Thus, it is probable that the Parks method did not substantially improve the efficiency of the estimators by correcting for heteroskedasticity and autoregression. In light of this result, the OLS model in (2) above is emphasized for interpretation, although the Parks estimates are presented for comparison.

The t-test was used to determine the significance of each of the estimated parameters, and the coefficient of determination (R^2) measured the amount of variation in the dependent variable accounted for by the explanatory variables.

Table 4.2 contains OLS estimates for the parameters of equation (1) -- a regression of the dependent variable on the intercept shifters alone. Table 4.3 contains parameter estimates for equations (2) and (3) -- a regression of the dependent variable on the intercept shifters and the economic variables. The Parks method estimates are presented alongside the OLS estimates. (R^2 and Durbin-Watson statistics were not computed for the Parks model.)

Interpretation of the OLS Model

The interpretation of any coefficient assumes ceterus paribus conditions hold with respect to each of the remaining explanatory variables. Also, projections outside the data range could lead to erroneous conclusions. Nevertheless, the estimated coefficients can provide insights into the relative responsiveness of the steer-heifer price differential to changes in each of the exogeneous variables.

Table 4.2. OLS Estimates of Regional Intercept Shifts in the Steer-Heifer Price Differential, No Economic Variables Included

Explanatory Variable	Estimated Coefficients	Estimated Standard Error	t[a]
Intercept (Virginia)	7.76	.56	13.84 (.0001)
R_1 (California)	-1.81	.82	-2.18 (.0326)
R_2 (Corn Belt)	-3.56	.79	-4.49 (.0001)
R_3 (Mountains)	-3.13	.79	-3.94 (.0002)
R_4 (Southeast)	-3.18	.79	-4.02 (.0001)
R_5 (Plains)	-1.62	.79	-2.05 (.0436)

[a] Significance levels are enclosed in parentheses.

Table 4.3. OLS and Parks Estimates of Impacts of Explanatory Variables on the Feeder Steer-Heifer Price Differential

Explanatory Variable	OLS Model			Parks Model		
	Estimated Coefficient	Elasticity Estimate	t	Estimated Coefficient	Elasticity Estimate	t
Intercept	1.03 (.65)[a]	--	1.57 (.12)[b]	1.45 (.59)	--	2.43 (.02)
$PHAY_{it}$ ($/ton)	.09 (.02)	.56	5.25 (.0001)	.09 (.01)	.56	6.69 (.0001)
Pe_{it} ($/cwt.)	.15 (.01)	.03	11.21 (.0001)	.14 (.01)	.03	12.85 (.0001)
$FED_{i't}$ ($/cwt.)	.41 (.13)	.11	3.04 (.0034)	.30 (.09)	.08	3.20 (.0021)
$CRN_{i't}$ ($/bu.)	1.09 (.29)	.35	3.70 (.0005)	1.06 (.24)	.34	4.36 (.0001)
$HOF_{i't}$ (ratio)	-1.11 (.61)	-.10	-1.81 (.0741)	-1.18 (.55)	-.10	-2.12 (.0371)
R_1 (California)	-1.92 (.44)	--	-4.34 (.0001)	-2.11 (.39)	--	-5.34 (.0001)
R_2 (Corn Belt)	-1.76 (.47)	--	-3.75 (.0004)	-1.83 (.42)	--	-4.36 (.0001)
R_3 (Mountains)	-1.53 (.54)	--	-2.79 (.0068)	-1.66 (.62)	--	-2.66 (.0095)

Table 4.3. Continued

Explanatory Variable	OLS Model Estimated Coefficient	OLS Model Elasticity Estimate	OLS Model t	Parks Model Estimated Coefficient	Parks Model Elasticity Estimate	Parks Model t
R_4 (Southeast)	-1.29 (.58)	—	-2.23 (.0290)	-1.32 (.63)	—	-2.08 (.0412)
R_5 (Plains)	.36 (.57)	—	.64 (.5240)	.28 (.56)	—	.50 (.6129)

[a]Estimated standard error.

[b]Significance level of t value for the estimated coefficient.

R^2 = .848 Durbin-Watson Statistic = 2.01

To make the interpretation of the coefficients more vivid, they are presented in percentage terms (elasticities) as well as absolute terms. The absolute coefficients -- which give the unit change in the dependent variable corresponding to a one unit change in each of the exogeneous variables -- are also presented in Table 4.3.

The percentage coefficients are computed for the economic exogeneous variables from the overall mean values of the variables in Table 4.1, and from the estimated coefficients in Table 4.3 as follows:

$$p = \frac{C/\overline{D}}{1/\overline{E}} = \frac{C\overline{E}}{\overline{D}} \qquad (4.10)$$

where:

p = the percentage change in the dependent variable corresponding to a one percent change in the exogeneous variable.

C = the estimated coefficient for the variable in Table 4.3.

$\overline{D}$ = the overall mean value of the dependent variable in Table 4.1.

$\overline{E}$ = the overall mean value of the exogeneous variable in Table 4.1.

Table 4.3 presents the elasticity estimates, which are rounded to the nearest .01 percent. Each should be interpreted as the percent change in the dependent variable generated by a one percent change in the exogeneous variable. These elasticities are true only for the mean variable values, and are expected to be different at variable values other than the means.

A one dollar per ton increase in the price of hay, PHAY, generated a .09 dollar increase in the steer-heifer price differential. At the mean variable values, this meant a one percent increase in the price of hay generated a .56 percent increase in the steer-heifer price differential. The price of hay appeared to explain changes over time rather than region since, among most regions, there was no significant difference in the average price of hay (Table 4.1).

A one dollar increase in the feeder calf price change from the three-previous-year average, Pe, generated a .15 dollar increase in the differential; this translates into a .03 percent in the dependent variable for each one percent increase in Pe, at the mean variable values. The influence of this variable was purely temporal since it's mean value (Table 4.1) did not differ significantly among the regions.

The steer-heifer fed cattle price differential had a statistically positive influence on the steer-heifer feeder cattle price differential, generating a .41 dollar increase in the latter for each dollar increase in the former. This meant a one percent increase in FED generated a .11 percent increase in the dependent variable at the mean variable values. From Table 4.1, the mean FED value differed significantly among the feeding regions, indicating that FED helped to explain regional differences in the dependent variable.

The proportion of heifers to steers on feed, HOF, had a statistically negative influence on the steer-heifer feeder price differential; furthermore, this variable helped to explain regional variation in the dependent variable, (Table 4.1), since it's mean value differed significantly among the regions. A one unit increase in HOF generated a decrease of 1.11 dollars in the dependent variable; likewise, a one percent increase in HOF generated a .10 percent decrease in the feeder sex price differential.

A one dollar increase in the price per bushel of corn resulted in a 1.09 dollar increase in the steer-heifer feeder price differential. A one percent increase in the corn price caused a .35 percent increase in the dependent variable.

A Measure of Explanation of Regional Variation

One measure of how well the OLS model explained regional variation in the dependent variable is by comparing mean values of the dependent variable by region (Table 4.1) with the OLS regional intercept shift estimates in Table 4.3.

The average difference between the Virginia and California sex price differential (in Table 4.1) was -1.81[3/] while the intercept estimate for the California region (R_1 in Table 4.3) was -1.92. Thus, it appears that the model did not explain the significant difference between the California and Virginia differentials, since it merely "shifted" the intercept by an amount approximately equal to the mean value difference.

However, the model did not estimate a significant intercept difference for the Plains region (in Table 4.3) although the differential in Virginia was significantly higher than the Plains differential. For the Corn Belt, Mountains and Southeast regions, the model consistently estimated an intercept which was lower in absolute value than the mean value differences: the average Corn Belt differential minus the average Virginia differential was -3.56 (in Table 4.1) while the intercept estimate for the Corn Belt region (in Table 4.3) was -1.76; in the Mountains, the mean value difference was -3.13 and the intercept difference was -1.53; in the Southeast, the mean value difference was -3.19 while the intercept estimate was -1.29.

Thus, with exception of the California region, the model explained substantial regional differences in the dependent variable, by the subjective criterion of comparing mean value differences to regional intercept estimates.

Another criterion for measuring the extent to which the economic variables accounted for a higher Virginia sex price spread is by comparing actual values of the differential with those predicted by the model in Appendix A, Table A.2 -- a regression of the dependent variable on the five economic variables, exclusive of the zero-one regional dummy variables.

Table 4.4 compares actual steer-heifer feeder calf price differentials with the differentials estimated by the five economic variables. Note, for example, that the model predicted on the average a $1.94 higher differential in Virginia than in the Corn Belt ($6.89 - $4.95). This compares with an actual average difference of $3.56 ($7.76 - $4.20), or 55% of the latter. Similarly, the variables explained, on the average, 55% of the difference between the Virginia and Mountain States differentials; and 64% of the difference between the Virginia and Southeast differentials.

The economic variables predicted a Virginia differential which was $2.15 higher than the Plains differential, while, on the average, the actual difference was only $1.63. Thus, the economic variables estimated a greater difference than actually existed. On the average, the model explained only 9% of the difference in California and Virginia sex price differentials.

Table 4.4. Actual and Predicted Steer-Heifer Feeder Price Differentials with the Five Economic Variables

Year	Virginia		Corn Belt		Mountain States		Southeast		Plains		California	
	actual	est.	actual	est.	actual	est.	actual	est.	actual	est.	actual	est.
1964	5.10	6.23	2.97	2.87	2.02	2.48	2.48	2.05	3.71	1.82	--	--
1965	6.63	6.07	3.23	4.45	4.18	3.90	3.40	3.17	4.81	2.63	--	--
1966	6.47	6.55	2.53	4.12	2.77	4.19	3.06	4.31	4.31	3.52	3.67	4.98
1967	6.67	5.93	2.66	3.68	3.20	4.11	2.87	4.17	4.03	3.56	3.92	4.87
1968	6.97	6.26	3.02	3.61	4.07	3.83	3.93	4.36	4.45	3.65	3.90	4.28
1969	6.43	5.86	3.94	4.57	4.61	4.80	4.37	5.21	5.03	4.48	3.97	5.25
1970	7.37	6.25	4.04	4.48	4.90	4.17	4.48	5.02	4.91	4.67	5.15	5.69
1971	7.17	7.04	4.49	4.59	5.18	5.03	5.99	5.03	5.96	4.95	4.50	5.97
1972	8.90	7.18	5.34	6.07	7.06	7.33	6.48	6.21	7.35	6.19	7.72	5.81
1973	10.22	9.07	7.21	9.88	9.23	10.17	8.82	8.31	11.75	8.87	10.16	10.89
1974	7.71	5.72	3.95	3.86	5.13	4.50	2.51	3.49	5.49	4.75	5.46	7.54
1975	10.85	8.97	6.75	6.15	3.88	5.95	2.96	4.64	8.84	5.72	7.61	8.60
1976	10.34	8.47	4.43	6.08	3.97	6.66	8.11	7.10	9.02	6.86	9.40	10.03
Average	7.76	6.89	4.20	4.95	4.63	5.16	4.57	4.85	6.13	4.74	5.95	6.71

It is useful to specify those portions of the Virginia steer-heifer feeder price spread, which can be attributed to each of the economic variable effects, and that portion which remains unexplained.

Table 4.5 delineates these effects for each variable and for each year in Virginia. The last column, unexplained error, is simply the actual Virginia sex price spread minus the sum of the economic variable effects. From the table, it might be inferred that the impact of HOF, within Virginia, is minor compared to the impacts of feed costs (PHAY and CRN), the fed cattle sex price spread (FED), and price expectations (Pe); however, the region to region impact may not be insignificant since the range in the HOF mean value was from .07 (in California) to .77 (Plains).

When observing feeder prices another issue arises: does an increase in the steer-heifer feeder price spread reflect increasing steer prices or declining heifer prices? More specifically, when moving out of the Virginia market, does a declining feeder sex price spread mean that Virginia heifers are lower priced than in some other market, or that Virginia steers are higher priced? In fact, no clear pattern is evident. In moving from Virginia to either the Corn Belt, the Mountain States, the Plains, or California, the average heifer calf price decreases while the average steer calf price increases.[4/] In moving from Virginia to the Southeast, both the average steer and heifer calf prices decline. (See Appendix D.)

Slope Shifters

The preceeding results suggest significant differences in the dependent variable among regions even after the economic variables are

Table 4.5. Estimated Effects of Each Economic Variable on the Virginia Steer-Heifer Price Differential

Year	Actual Virginia Differential[a]	Effect of the Economic Variables[b]					Unexplained Error
		Pe	PHAY	CRN	FED	HOF	
1964	5.10	-.6	3.41	1.22	2.32	-.09	-1.70
1965	6.63	.24	3.13	1.22	1.59	-.11	.56
1966	6.47	.62	3.24	1.37	1.40	-.12	.04
1967	6.67	.51	3.06	1.08	1.37	-.11	.76
1968	6.97	.20	2.97	1.09	2.19	-.14	.66
1969	6.43	.54	3.06	1.19	1.14	-.10	.60
1970	7.37	.67	3.20	1.40	1.05	-.11	1.16
1971	7.17	.80	3.24	1.15	1.93	-.11	.16
1972	8.90	1.92	3.28	1.40	.53	-.10	1.87
1973	10.22	2.89	3.60	2.40	.04	-.12	1.41
1974	7.71	-2.52	3.96	2.82	1.62	-.11	1.94
1975	10.85	-2.23	4.28	2.31	4.80	-.09	1.78
1976	10.34	.71	5.45	2.26	1.39	-.19	.72

[a]/Dollars per cwt. spread between choice, 400-500 lb. feeder steers and 400-500 lb. feeder heifers.

[b]/These values were obtained by multiplying each estimated regression coefficient by it's corresponding value, each year, in Virginia.

included. A possible explanation of these differences is offered by the inclusion of zero-one slope shifter variables. As mentioned in the final section of Chapter III, subjective experimentation with slope shifters for the economic variables suggested some regional differences in the response of the dependent variable to changes in the exogeneous variables; and the price of corn, CRN, was the only variable found to exhibit regional slopes which were for the most part significantly different from the omitted region, Virginia.

Another OLS model was estimated, replacing the regional intercept shifters with regional corn price slope shifters. The results of this model are presented in Appendix A.

The reason for estimating this model is that there may be a theoretical basis for expecting that the response to corn price changes may differ among regions. This theoretical basis involves the feed conversion ratio of heifers relative to steers in the feedlot. In Chapter II (c.f. p. 16) it is hypothesized that an increase (decrease) in feed prices has a positive (negative) influence on the steer-heifer feeder price spread. This hypothesis was based on the premise that heifers are less feed efficient than steers. The relationship was represented by estimating a coefficient for the corn price in the statistical model. If relative feed efficiencies are allowed to vary by region, a separate coefficient for the corn price would be expected for each region.

To the author's knowledge, regional feed efficiency data is non-existent. Estimation of separate corn price coefficients for each region, however, may provide a proxy for relative feed efficiencies, region by region, since the estimated corn price coefficient is tied to some assumed feed conversion ratio for steers and heifers.

For the model in Appendix A, the proportion of heifers to steers on feed, HOF, did not have statistical significance; whereas in the OLS model in Table 4.3, HOF was significant at the 10 percent level. This result would seem to indicate a high degree of interaction between the number of heifers fed and regional differences in the corn price coefficient. Thus, there is some evidence that the relative number of heifers to steers fed and the regional response to corn price changes are jointly determined and may, in fact, be reflecting the same phenomenon -- the phenomenon of regional differences in the feed efficiency of heifers.

1/The set of all i does not exhibit a one-to-one relationship with the set of all i', since i=(1,...,6) and i'=(1',...,5'). This descrepency arises because, under the assumptions in Chapter III, one feeding region (Plains) serves as the destination point for two stocking regions (Plains, Southeast).

2/The Parks GLS estimating procedure, which is specific for time-series cross-section data, is available on the SAS'76 computer package.

3/California mean minus Virginia mean.

4/The reader should interpret reported absolute price levels for Virginia carefully, since price data were obtained from the Virginia Special Sales, in which the overall quality of cattle is generally higher than in most other types of auctions -- thus, reported absolute prices may not be representative of actual Virginia prices. However, this is no reason to suspect that the sex price differential, as reported, is not representative.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were: (1) to establish whether significant variation in the feeder steer-heifer price spread occurs across regions in the U.S.; (2) to identify those physical and economic attributes which differentiate heifers from steers over the time and space dimension; (3) to specify the interrelationships between these attributes and the market sex price spread as a measure of relative value; and (4) to employ these interrelationships to provide some basis for judging any divergence between actual and "perfect market" sex price spreads.

A summary of the methodology, statistical procedures, and statistical results is presented. Further, conclusions and implications based upon the results are presented. Finally, the limitations of this study and suggested future research are discussed.

Overall Summary

A statistical test of feeder calf price data indicated that the sex price spread in Virginia is significantly greater than the sex price spread nationwide. This fact is of concern to Virginia beef producers since the state is primarily a cow-calf producer.

From the theory of supply and derived demand (and based upon the biological differences between steers and heifers), an economic model was developed to pinpoint those factors which give rise to the sex price spread. The economic model was transformed into a statistical model, and numerical estimates of the parameters were obtained.

The statistical model was estimated by the methods of ordinary and generalized least squares for pooled time-series and cross-section data. The parameter estimates provided a basis for judging the responsiveness of the steer-heifer price spread to changes in the exogeneous economic variables. All data were taken from the period 1964 through 1976, with exception of the California region for which 1964 and 1965 data were missing.

The disturbance terms in the OLS model appeared to follow a non-autoregressive, homoskedastic scheme since GLS parameter estimates didn't appear to differ significantly from those in the OLS model. It was concluded that the OLS model probably provided unbiased and efficient estimates with the normal assumptions underlying least squares.

Conclusions

All exogeneous economic variables were statistically different from zero at the 10 percent level of significance: the price of hay, the rate of feeder calf price change, the fed cattle sex price spread, the proportion of heifers to steers on feed, and the price of corn accounted for 84.8 percent of the variation in the steer-heifer feeder price differential when regional zero-one intercept shifters were included. The economic exogeneous variables alone (without the dummy variables) accounted for 71.6 percent of the variation in the dependent variable (Appendix A).

Analysis of the mean values of the variables indicated that changes in conditions affecting the supply relation (hay prices and the rate of feeder calf price change) as well as the price of corn contributed to changes in the steer-heifer feeder price differential over time. The fed cattle sex price differential and the proportion of heifers to steers on feed influenced the feeder sex price spread over region as well as over time. Subjective experimentation with slope shifter variables suggested that the response to corn price changes may be different for different regions; and the proportion of heifers to steers on feed is highly interactive with varying regional responses to corn price changes, suggesting that the number of heifers fed may, in part, reflect the phenomenon of regional differences in the feed efficiency of heifers relative to steers.

Since the feeder price differential is implicitely a function of feeder cattle movement patterns, a change in movement patterns implies a change in the differential. More concretely, if Virginia feeder cattle were shipped to regions other than the assumed destination points in this study, a different steer-heifer price spread may be expected.

A major objective of this study was to provide some basis for judging the divergence between actual and "perfect" market feeder sex price spreads, particularly in Virginia. The compelling question becomes: is the steer-heifer feeder price spread in Virginia higher than one might expect under perfectly competitive conditions?[1/]

One way of answering this question is to contrast actual Virginia price spreads to those generated by the model in Chapter IV, which might be considered the competitive or efficient model since it responds to changes in hypothesized economic variables. These variables, to an extent, explained the higher Virginia feeder price spread; however, regional differences persisted in the final model.

Based upon this research, the steer heifer feeder price spread in Virginia may be expected to exceed the sex price spread in other markets, for most regions during most years; this results principally from the influence of two demand variables: the fed cattle sex price spread and the heifer-steer proportion on feed. However, the estimated effect of these two variables was not sufficient to account for the entire feeder sex price spread in Virginia. One possible reason is that some relevant economic variable(s) were not specified in the model; or, pricing distortions may exist due to a deficiency of information among buyers and sellers, or because the grading system fails to accurately reflect quality differences.

Actually, a variable reflecting the productive efficiency of the several markets -- i.e., the feed efficiency of heifers relative to steers -- may be appropriate in describing price relationships since the technical progressiveness of an industry is one aspect of productive efficiency, which in turn bears upon marketing efficiency.[2/] The author was unsuccessful in attempts to find a measure of the feed efficiency of heifers relative to steers; thus it is possible that not all economic variables were included.

Limitations

The conclusions and implications expressed here are inevitably limited by the mathematical form of the model and its specification. In addition, a high degree of multicollinearity between the price of hay and the price of corn (a correlation coefficient of .80 noted in Appendix B) may have contributed to large standard errors for these two coefficients.

A second limitation concerns the assumption that heifers (or steers) of a given weight, age, and grade are homogeneous products nationwide, which implies that heifers (or steers) produced in one stocking region are perfect substitutes for animals of the same sex produced in other stocking regions; and that feedlot operators are indifferent as to their source of supply. This may or may not be a valid assumption.

Third, cattle price data were derived from unweighted monthly averages for both feeder and fed cattle. In years characterized by rapid price changes during the fall months (such as 1973), the three month average price estimate could be considerably biased since prices were not weighted by volume.

A fourth limitation arises due to assumptions regarding feeder cattle movements since the relevant derived demand relation, and thus the accuracy of the demand variable impacts, depends upon the plausibility of assumed feeder movement patterns. There are two reasons why the model may fail to represent reality in this respect: (1) assumed feeder movement patterns are partly subjective and imprecise; and (2) the model does not account for changing movement patterns over time.

Future Research

It is hoped that this study will provide a foundation for future price differential forecasting models. The information could be helpful to individual producers who must decide between steers and heifers as competing commodities based upon expected price differentials. More sophisticated forecasting techniques applied to the results of this research effort could provide a method of hedging heifer cattle in the futures market. In the same way that past price relationships between local cash markets and the futures market provide an estimate of the selling basis, the relationship between steer and heifer prices could provide an estimate of the "selling basis" for heifers when steers are hedged.

In addition, a research effort to determine whether or not heifers (or steers) can be considered homogeneous products across the U.S. warrants attention. Variation in the sex price spread could be due to qualitative factors that the current grading system does not recognize, such as risk of pregnancy in heifers.

Finally, it is hoped that future research can be directed towards the three questions: (1) why is the fed cattle sex price spread higher in some regions than in others? and (2) why does the proportion of heifers to steers fed negatively influence the feeder sex price spread? and (3) since some feedlot operators apparently specialize in either heifers or steers, why do they tend to prefer one sex over the other for feeding? Although this last question may be related to feed efficiencies, further research would require regional feed conversion data from fed cattle producers.

1/ In this context, a perfectly competitive feeder market implies: (1) perfect knowledge; (2) free entry in all directions; (3) one buyer or seller cannot influence price; and (4) product homogeneity.

2/ Productive efficiency and pricing efficiency are two attributes of marketing efficiency, as suggested by Bressler and King, (pp. 410-414).

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APPENDICES

APPENDIX A

SUPPLEMENTARY MODELS

This Appendix contains information which supplements the discussion in Chapter IV.

Table A.1 exhibits an OLS model in which regional intercept shifters were replaced with regional corn price slope shifters. In addition to the exogeneous variables defined previously, the regional corn price coefficients for the respective stocking regions are:

CRN = the corn price coefficient for Virginia (the omitted region).

$CRN + CRNR_1$ = the corn price coefficient for the California region.

$CRN + CRNR_2$ = the corn price coefficient for the Corn Belt region.

$CRN + CRNR_3$ = the corn price coefficient for the Mountains region.

$CRN + CRNR_4$ = the corn price coefficient for the Southeast region.

$CRN + CRNR_5$ = the corn price coefficient for the Plains region.

Table A.2 exhibits another model in which the dependent variable was regressed against the five economic exogeneous variables without the inclusion of slope or intercept shifters.

Table A.1. OLS Model with Regional Corn Price Slope Shifter Estimates

	Estimated Coefficient	Estimated Standard Error	t[a]	$CRN+CRNR_i$
Intercept	-.4219	.5471	-.77	--
$PHAY_{it}$	.104	.017	6.08 (.4434)	--
Pe_{it}	.155	.012	12.02 (.0001)	--
$FED_{i't}$	.414	.128	3.22 (.0021)	--
$HOF_{i't}$	-.617	.464	-1.33 (.1889)	--
CRN (Virginia)	1.72	.353	4.88 (.0001)	--
$(CRN)(R_1)$ (California	-1.04	.205	-5.13 (.0001)	.68
$(CRN)(R_2)$ (Corn Belt)	-1.09	.233	-4.70 (.0001)	.63
$(CRN)(R_3)$ (Mountains)	-1.09	.248	-4.38 (.0001)	.63
$(CRN)(R_4)$ (Southeast)	-.92	.254	-3.64 (.0005)	.80
$(CRN)(R_5)$ (Plains)	.02	.252	0.08 (.9332)	1.70

[a] Significance levels are enclosed in parentheses.

R^2 = .865 Durbin-Watson Statistic = 1.98

Table A.2. OLS Model with the Five Exogeneous Economic Variables

	Estimated Coefficient	Estimated Standard Error	t[a]
Intercept	-.382	.742	-.51 (.6087)
PHAY	.101	.022	4.53 (.0001)
Pe	.158	.017	8.83 (.0001)
FED	.627	.163	3.85 (.0003)
HOF	-.861	.507	-1.7 (.0939)
CRN	.939	.372	2.52 (.0140)

[a] Significance levels are enclosed in parentheses.

R^2 = 71.1 Durbin Watson Statistic = 1.09

APPENDIX B

The correlation matrix of the exogeneous variables for the estimated models in Chapter IV are exhibited in Table B.1.

Table B.1. Matrix of Correlation Coefficients

	D	PHAY	Pe	FED	CRN	HOF	R_1	R_2	R_3	R_4	R_5
D	1.0	.5722	.2494	.2787	.4519	-.3908	.0233	-.2508	-.1660	-.1771	.1263
PHAY		1.0	-.4068	.2374	.8047	-.2983	.1725	-.1972	.0282	-.0571	-.1269
Pe			1.0	-.2850	-.4642	-.0199	.0098	.0080	-.0179	-.0076	.0063
FED				1.0	.1588	-.2819	-.0997	.0485	-.1085	-.1570	-.1695
CRN					1.0	-.1970	.1662	-.0906	.0090	-.0147	-.0241
HOF						1.0	-.5394	-.0033	.2978	.3754	.3295
R_1 (California)							1.0	-.2000	-.2000	-.2000	-.2000
R_2 (Corn Belt)								1.0	-.2000	-.2000	-.2000
R_3 (Mountains)									1.0	-.2000	-.2000
R_4 (Southeast)										1.0	-.2000
R_5 (Plains)											1.0

APPENDIX C

This Appendix contains the data and method used to calculate feeder sex price differntials in Chapter II, Table 2.1. The objective of this analysis is to calculate steer and heifer feeder prices that will give an equal return per dollar of cost in feeder animals under a scheme of increasing feed prices.

First, returns per head of heifer are set equal to returns per head of steer:

$$\text{(C.1)} \qquad \text{Returns per head of steer} = \text{Returns per head of heifer}$$

where:

$$\text{(Return per head)} = \text{(slaughter wt.)(slaughter Price)} - \frac{\text{lb. feed}}{\text{lb. gain}} \frac{\text{cost}}{\text{lb. feed}} \text{(lb. gain)} - \text{(per head nonfeed cost)} - \text{(feeder wt.)(feeder price)}$$

Now, if a 600 lb. feeder steer sells for \$36/cwt., and a 500 lb. heifer sells for \$30/cwt., then 120 heifers could be purchased for the same amount of money needed to buy 100 steers.

Thus, to compute a breakeven price differential based upon equal returns per dollar of feeder animal cost, return per head of heifer (the left-hand side of expression C.1) must be multiplied by:

$$\text{(C.2)} \qquad \frac{\text{(feeder wt. steer)} * \text{(feeder steer price)}}{\text{(feeder wt. heifer)} * \text{(feeder heifer price)}}$$

to obtain:

$$\text{(C.3) Return per head steer} = \text{Return per head heifer} \quad \frac{\text{(feeder wt. steer)*(feeder steer price)}}{\text{(feed wt. heifer)*(feeder heifer price)}}$$

Expression (C.3) sets the return per dollar of cost in steers equal to return per dollar of cost in heifers.

From the data in Table C.1, the feeder heifer price was calculated under various feed price conditions by solving expression (C.3) for the feeder heifer price. All other factors, including the feeder steer price, remained invariant. The results of these calculations are presented in Table 2.1, Chapter II.

Table C.1. Data used to Calculate Breakeven Price Differentials[a]

	Steers	Heifers
Slaughter wt. (lbs.)	1075.	910.
Slaughter price ($/lb.)	.45	.44
Lb. feed/lb. gain	9.18	9.70
Lb. gain (lb.)	420.	362.
Per head non-feed cost ($)	60.	60.
Feeder weight (lb.)	655.	548.
Feeder price ($/lb.)	.36	--

[a] SOURCE: Hoelscher.

[b] Slaughter and feeder prices correspond roughly to fall 1976 levels, nationwide.

APPENDIX D

Steer and Heifer Calf Prices, Average, 1964-1976, Fall Season

Region	Steer Price[a]	Heifer Price
Virginia	37.45	29.69
California	36.43	30.46
Corn Belt	35.71	31.50
Mountains	36.74	32.09
Southeast	32.52	27.94
Plains	35.99	29.86

[a] Prices reported in dollars/cwt. of choice, 400-500 lb. steers and heifers.

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AN ANALYSIS OF FEEDER STEER-HEIFER
PRICE DIFFERENTIALS IN THE U.S.

by

David L. Jessee

(ABSTRACT)

Because of a prevalent concern that feeder heifer prices are often bid below their true value, particularly in Virginia, a study was made of factors affecting price differentials between steers and heifers, and of variations in these differentials across regions and over time. The fall market sex price differential for feeder calves in Virginia (1964 through 1976) was compared to the differential in five other regions: the Corn Belt, the Southeast, the Plains, the Mountain States, and California.

A cross-section time-series model was designed in which sex price differentials across years and regions were regressed against hay prices, short-term feeder cattle price expectations, the corn price, the fed cattle sex price differential, and the heifer-steer proportion on feed. In addition to these economic variables, five regional zero-one intercept shifters were included; all explanatory variables accounted for 84.8 percent of the variation in the feeder sex price differential, while the economic variables alone accounted for 71.6 percent of the variation across regions and over time.

Based upon this research, the steer-heifer feeder price differential in Virginia may be expected in most years to exceed the sex price spread in other markets; however, the estimated effect of the economic variables

was not sufficient to entirely account for the higher Virginia sex price differential. One possible reason is that some relevant economic variable(s) were excluded; or pricing distortions may exist due to a lack of price information or due to imperfections in the grading system.