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An econometric analysis of the quarterly demand and supply relationships for feeder cattle in the United States

Joe T. Davis

To the Graduate Council:

I am submitting herewith a dissertation written by Joe T. Davis entitled "An econometric analysis of the quarterly demand and supply relationships for feeder cattle in the United States." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

Raymond Daniel, Major Professor

We have read this dissertation and recommend its acceptance:

Irving Dubov, Emmit Rawls, Kieth Phillips

Accepted for the Council:

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(Original signatures are on file with official student records.)

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AN ECONOMETRIC ANALYSIS OF THE QUARTERLY DEMAND AND SUPPLY RELATIONSHIPS FOR FEEDER CATTLE IN THE UNITED STATES

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee

Joe T. Davis

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ABSTRACT

The overall objective of this study was to develop a price forecasting model which would give the producers of feeder cattle, feedlot operators, and other segments of the beef cattle industry more than just a hunch as to future feeder cattle price movements. The specific objectives were: (1) develop an econometric model to identify the major factors influencing the quarterly demand and supply of feeder cattle in the United States; (2) develop alternative quarterly feeder cattle price forecasting models using the econometric structural relationships estimated above; and (3) evaluate the interrelationships among the various markets in the beef cattle industry.

An econometric model consisting of eight behavioral equations and two market clearing equations were developed to describe the relationships within and among the feeder cattle, slaughter cattle, and retail sectors of the beef industry. The behavioral equations were fitted to quarterly data for the years 1960-1972 using the two-stage least squares technique.

The farm level demand for feeder cattle was normalized on the current price of feeder cattle. The major factors hypothesized to affect the price of feeder cattle were the current quantity of feeder cattle, the price of corn, the number of head on feed, the current price of slaughter cattle, the short-term interest rate, and quarters of the year.

The farm level supply function was normalized on the current quantity of feeder cattle. The major factors hypothesized to affect the

quantity of feeder cattle supplied were the current price of feeder cattle, calf crop lagged two quarters, the price of feeder cattle lagged four quarters, a time variable, and quarters of the year.

The demand relationship for slaughter cattle was normalized on the current price of slaughter cattle and the supply relationship was normalized on the current quantity of slaughter cattle. The major factors hypothesized to affect the price of slaughter cattle were the quantity of slaughter cattle, the retail price of beef, cow slaughter, cold storage holdings of beef, wage rate in the meat packing industry, and quarters of the year. The major factors hypothesized to affect the quantity of slaughter cattle supplied were the current price of slaughter cattle, price of feeder cattle lagged two quarters, the price of corn lagged two quarters, a time variable, and quarters of the year.

A marketing margin was used to connect the prices at the farm level to the prices at the retail level. The factors affecting the farm to retail marketing margin for beef were hypothesized to be the quantity of slaughter cattle moving through the market, the wage rate in the meat packing industry, the price of slaughter cattle, and time.

Retail level demand equations for beef, pork, and chicken were developed. The major factors affecting the demand for these three substitute meats were their respective prices and quantities, income, and quarters of the year.

The results indicated that the price and quantity of feeder cattle were simultaneously determined. The major factors affecting the price of feeder cattle were the quantity of feeder cattle and the price of slaughter cattle. The demand relationship was found to be significantly higher in the fall quarter. The major factors affecting the quantity of feeder cattle supplied were the price of feeder cattle and the time variable.

The results indicated that the major factors affecting the price of slaughter cattle were the retail price of beef and cow slaughter while the major factors affecting supply were the price of slaughter cattle, the price of feeder cattle lagged two quarters, and time.

Alternative forecasting models were developed to predict the price and quantity of feeder cattle. The most promising model that could be used to predict feeder cattle prices and quantities was a model which included all independent variables in the first stage of the TSLS technique. However, data for variables measured in time period "t" would not be available at the time the prediction is needed. Therefore, a model using all independent variables in the first stage with all variables measured in time period "t" lagged two quarters was used to predict the price and quantity of feeder cattle for the five quarters following the sample period. The predictions were evaluated on the basis of the direction of change and how closely the predicted values approximate the actual value. The model correctly predicted two out of five directions for price and three out of five direction of change for quantity. The largest deviation between the actual price and the predicted price of feeder cattle using this model was $12.05 which occurred in the summer quarter of 1973.

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CHAPTER I

INTRODUCTION

I. OVERVIEW OF THE BEEF CATTLE INDUSTRY

Beef and beef products represent the most important meat in the American diet. During 1960, the average per capita consumption of beef was around 85 pounds. This increased to 109 pounds in 1968 and to 116 pounds in 1972. Total beef consumption in the United States amounted to almost 24 billion pounds in 1972 (USDA Livestock and Meat Statistics, 1972).

Producers have been steadily increasing the size of their beef herds to meet this increasing demand for beef by the American consumer. The number of beef cows on farms in the United States at the beginning of 1960 was over 26 million head. The number of cows increased to over 41 million in 1973 (USDA Livestock and Meat Statistics, 1972).

Before 1950, most of the beef consumed in America came primarily from grass fed animals. Relatively few animals were fed any substantial amounts of grain before slaughter. However, since 1950, the development of grain feeding has reversed the process and now the majority of the beef that is consumed comes from grain fed animals. This increase in cattle feeding is illustrated by the decline in calf slaughter in recent years and the increase in the number of animals going through feedlots.

This increase in grain feeding influenced the development of the feeder cattle sector of the beef industry. The production of beef cattle for further pasture fattening or grain feeding is an old industry. However, specialization in the production and marketing of feeder cattle designed specifically for further feedlot finishing as it now exists is relatively new (Armstrong, 1968, p. 8).

The demand for particular types of beef by the consumer has and will continue to cause changes in the cattle feeding industry. The demands of the cattle feeding industry for feeder animals that will produce the kind and quality of beef demanded will influence the organization and operation of the feeder cattle industry.

II. PROBLEM AND OBJECTIVES

While the marketing system for livestock in total has been called the most competitive of all marketing systems in agriculture, there are some apparent differences in competition within the beef cattle industry. The feeder cattle industry probably more nearly approaches the economic definition of a purely competitive industry than either the cattle feeding or beef slaughtering and processing segments of the industry (Armstrong, 1968, p. 9).

In recent years, the other segments of the industry have shown some indication of structural change in terms of concentrating large numbers of animals in large enterprises. However, the feeder cattle industry has remained basically one of numerous small independent producers spread over much of the United States, especially the southeast and southwest. These producers have a relatively homogeneous product with no one producer having sufficient volume to affect the market price. Barriers to entry into the industry are low or nonexistent and resources seem to flow freely into and out of the industry.

While there appears to be little structural change occurring in the feeder cattle industry, there are factors which impede the marketing of feeder cattle. Feeder cattle are produced on many farms as a secondary enterprise with variations in size, grades, and management practices. Because of these and other factors, price reporting and dissemination in this sector of the beef cattle industry is far from perfect.

The overall objective of this study was to develop a model which will give the producers of feeder cattle, feedlot operators, and other segments of the beef cattle industry more than just a hunch as to future feeder cattle price movements. This would be useful in planning production and marketing in all segments of the industry and also reduce some of the uncertainty of prices.

The specific objectives of this study were:

1. Develop an econometric model to identify the major factors influencing the quarterly demand and supply of feeder cattle in the United States.
2. Using the above relationships, develop one or more quarterly price forecasting models for feeder cattle.
3. Evaluate the interrelationships among the various markets in the beef cattle industry.

III. SUMMARY OF PAST RESEARCH

The beef cattle industry has been the subject of a considerable amount of economic research. In order to put this study into perspective with previous work, several of the past efforts will be reviewed and summarized. Most of the studies reviewed in this section dealt with the slaughter cattle or retail sectors of the beef cattle industry since little econometric work has been directed to the problems involved in the feeder cattle sector.

A study of the quarterly interrelationships between market levels for beef and pork was conducted by Maki (1959) in an attempt to obtain beef cattle and hog price forecasting equations. Two models of the market relationships were developed in the study to obtain price forecasting equations for the farm, wholesale, and retail markets. The first model considered the dressed, or wholesale, meat market as the critical pricing level where prices adjusted to predetermined levels of beef and pork quantities. The second model considered the national retail market as the critical pricing level. Retail prices were expressed as a function of beef and pork consumption, poultry prices, disposable income, and tastes. Wholesale and farm prices were assumed to adjust to quarterly changes in retail prices through retail and wholesale margin relationships.

The margin relationships developed by Maki are of special interest. Once the pricing equations were estimated for the critical levels, then farm level and wholesale or retail level prices were expressed as a function of the critical price. The findings showed that a one cent per pound increase in the reported wholesale beef price was associated with a 0.7 cent per pound increase in the average beef cattle price and a one cent per pound increase in the average retail beef price.

Retail to wholesale and wholesale to farm margin equations were then derived from the price reaction equations. Maki's results indicated that quarterly beef and pork margins cannot be considered fixed and the effects of volume and price changes on margins should be explored in a structural model of the beef or pork sector.

Trierweiler and Erickson (1965) conducted a study that was concerned with identification of supply responses of the cow-calf operator in 23 homogeneous regions of production in the United States. Structural economic models were developed for the number of beef calves born in each of the 23 regions and the United States as a whole.

In this model it was assumed that beef production was divided into two relatively distinct areas of specialization: cow-calf operations and feedlot operations. Primary product of the cow-calf operator was beef calves to be fed, while that of the feedlot operation was carrying feeder cattle through feeding to be slaughtered.

Various factors which affect the supply of beef calves were used as independent variables. The independent variables used to reflect the supply response were stocker-feeder calf price, number of cows on hand at the beginning of the year, range or pasture condition, and a time variable.

The coefficients for cows on hand, lagged one year, in the regional calf production equations were generally less than the average calving rate within each region. The percentage change was low in the number of beef calves as a result of a one percent change in the stocker-feeder price lagged three years. The response in calf numbers to changes in range conditions, lagged one and one-half years, was slightly greater than the stocker-feeder price. Response to the technological variable was very low.

Prato and Havlicek (1968) analyzed the monthly farm level demand and price of slaughter cattle for the 1948-1964 period. The study was mainly concerned with identifying major factors which influence farm level demand and prices of slaughter cattle, determining the nature of the monthly demand for slaughter cattle, and assessing the impacts which changes in these major factors have on quantities and prices of slaughter cattle at the farm level.

A model consisting of three overidentified equations containing three endogenous variables and five exogenous variables was used to relate the factors affecting the monthly price and quantity of cattle slaughtered and to estimate the monthly demand for slaughtered cattle. The demand relation expressed the price received for slaughter cattle as a function of the per capita volume of slaughter cattle, per capita cold storage holdings of beef, and per capita personal income. The supply relation expressed the quantity of slaughter cattle supplied as a function of the current price of slaughter cattle, the price received for slaughter cattle the previous month, the price of feeder cattle lagged one year, and the current price of corn. The price received by farmers for slaughter cattle, the volume of cattle slaughtered, and cold storage holdings of beef were jointly determined in the model.

It was found that a one percent increase in the volume of cattle slaughtered was associated with a greater than one percent decrease in the price of slaughter cattle. Increases in consumer income increased the demand and raised the price of slaughter cattle.

A study by Hayenga and Haeklander (1970) focused on the monthly farm level demand for cattle and hogs. The independent variables were live cattle price, live hog price, pork cold storage, cattle supply, and hog supply.

Results of the study indicated that cattle and hog prices at the packer level were responsive to quantities slaughtered, personal income, and season of the year expressed as [0,1] intercept dummy variables for months.

Quantities supplied of cattle and hogs were found to respond to their respective prices and inventory levels. The price of hogs was found to have an unexpected negative influence on quantity supplied. The authors concluded that:

> One possible explanation for the direction of producer response is the idea that hog producers expect the most recent price trend to be continued. Consequently, they may sell less in the current month because they believe prices will continue to increase if they have been doing so in the very recent past. (Hayenga and Haeklander, 1970, p. 543)

Myers (1970) developed a simultaneous monthly model which concentrated on the hog-pork sector but also included the cattle-beef and broiler relationships. The primary objective was to estimate the structural relationships involved in the various markets. A secondary objective was to develop a short-term prediction model.

The model consisted of eight simultaneous equations which were normalized on the monthly supply of live hogs for slaughter, the monthly supply of live cattle for slaughter, the farm to retail margin for pork, the farm to retail margin for beef, the monthly supply of pork for consumption, the monthly demand for pork for consumption, the monthly demand of beef for consumption, and the monthly demand of broilers for consumption. The study covered the months from 1949-1966.

The development of a theoretical model of monthly slaughter animal supply as developed by Myers was of particular interest. He assumed that the quantity of animals of slaughter weight at the beginning of a month plus the quantity reaching slaughter weight during the month were predetermined by past production decisions. However, the quantity and average weight of animals actually supplied for slaughter depend upon expected revenue from carry-over versus expected cost of carry-over. Quantity supplied for slaughter for a given month was stated as a function of present farm level price, expected farm level price, costs of carry-over, and number of animals of slaughter weight.

The slaughter supply equations estimated contained only the current farm price. The estimated coefficients for price in the equation for cattle and hogs were both negative. This unusual result was rationalized on the basis that the current price variable also reflected expected price, thus the estimated coefficients were the sum of current and expectational forces. Since both prices were negative in the two supply equations, Myers concluded that expected prices had a stronger influence on quantities supplied than current price.

CHAPTER II

ECONOMIC MODEL

I. THEORETICAL FRAMEWORK

The Concept of Derived Demand

The analysis of the demand for a raw farm product is based upon the concepts underlying the theory of derived demand. The demand for a farm product which is to be processed or changed in form is derived from the consumer demand for the final product. Middlemen demand a farm product because they believe that the demand for the finished product they produce will command a price that will more than repay their costs of purchasing, processing, and marketing the item. Therefore, the demand for a farm product by a processor or middleman not only depends upon the demand of the consumer for the finished product but also the costs of making that product available to the consumers (Nicholls, 1941, Chapter I).

Conclusions of the Theory of Consumer Behavior

The theory of consumer behavior underlies the theory of individual consumer demand and the theory of aggregate market demand. Two conclusions of consumer behavior form the basis of the law of demand. First, the quantity of a commodity purchased varies inversely with the price of the commodity, while holding the prices of all other commodities constant. Therefore, the demand curve of a particular product is downward sloping. The market demand for a product is the summation of the quantities taken by each consumer at various prices while holding the prices of all other commodities constant. Market behavior is, therefore, based on the behavior of consumers in the aggregate, and market expectations may be derived from the theory of consumer behavior.

The second theoretical conclusion is that the quantity demanded of an commodity is a funcition of the price of that commodity, prices of all other commodities, consumer income, and tastes and preferences.

Demand at Various Levels of the Market

It is often said that "price is determined by the interaction of supply and demand in the market." This statement is correct if one is speaking of supply and demand in the same market. However, if the aggregate demand applies to the demand by consumers for a product at the retail market, and the supply is the quantity offered for sale at various prices by the farmer, then the above statement has no significance.

The demand for beef, or any good, at the various levels of the marketing channel requires consideration of the costs involved at each level. Assuming a perfect market in which there are three levels of supply (producer, packer, and retailer) and three levels of demand (consumer, packer, and retailer) the following relationships can be derived. The demand for beef at the retail level is the primary or basic demand. The consumer demand is the demand facing the retailer. Given this demand, the retailer demand (that facing the packer) is derived from the consumer demand for the product. The packer demand (that facing the producer) is derived from the retailer demand.

Supply at Various Levels of the Market

Many activities are performed in getting a feeder calf from the farm level to a marketable product at the retail level. These activities involve finishing feeder calves to an acceptable slaughter weight, slaughter and processing of slaughter cattle, and distribution and retailing of the final product from the packer. Therefore, a supply relationship exists at the various levels in the market. The supply at one level may be one of the inputs in the process at the next level. The production firms at the various levels of the market are assumed to operate in a perfectly competitive market on both the input and output markets. These firms are also assumed to maximize profits subject to their implicit production function. Labor, capital, feed, and cattle are major inputs that enter the production process at various levels in the market. For example, feeder cattle are used by the feedlot operator in producing slaughter cattle and slaughter cattle are used by the packer in furnishing beef products to the retail sector.

From the first order conditions of profit maximization it is possible to derive the quantity of output as a function of price. The horizontal summation of these supply curves over all firms would yield what may be called the constant industry supply of output.

Aggregation viewed in this simple framework assumes that prices of inputs and outputs remain constant for the industry as a whole as for the individual firm. Thus, if the industry is facing a downward sloping retail demand curve and a somewhat upward sloping supply curve for some of the inputs, such an assumption of constant prices may invalidate the model. It is true that aggregate functions computed as the horizontal summation of the firms' supply function would overestimate the industry reaction to certain price changes. However, theory was used in the search for the relevant variables entering the behavioral relationships and not the magnitudes of the effects.

II. OVERVIEW OF THE MODEL

The economic framework within which the demand and supply of feeder cattle, slaughter cattle, and retail beef are determined has been discussed. Therefore, the factors which determine the demand and supply at the various levels in the market must be brought together in an economic model.

Demand and supply relationships for the feeder cattle, slaughter cattle, and retail markets along with appropriate market clearing equations comprise the economic model that was hypothesized to represent the feeder cattle industry. This model represents the different economic and behavioral hypothesis concerning the important variables which were assumed to affect price and quantity of feeder cattle, slaughter cattle, and retail beef. The relationships at each level of the market and the interrelationships between the various levels are presented in Figure 1. The price and quantity at the various levels were hypothesized to be simultaneously determined. This was based on the possibility that producers at the slaughter cattle and feeder cattle levels have the option of holding animals from the market depending on current price and economic conditions at that time. When producers have the option of alternating interquarterly marketings based on continually changing current information, then simultaneity is likely to exist.

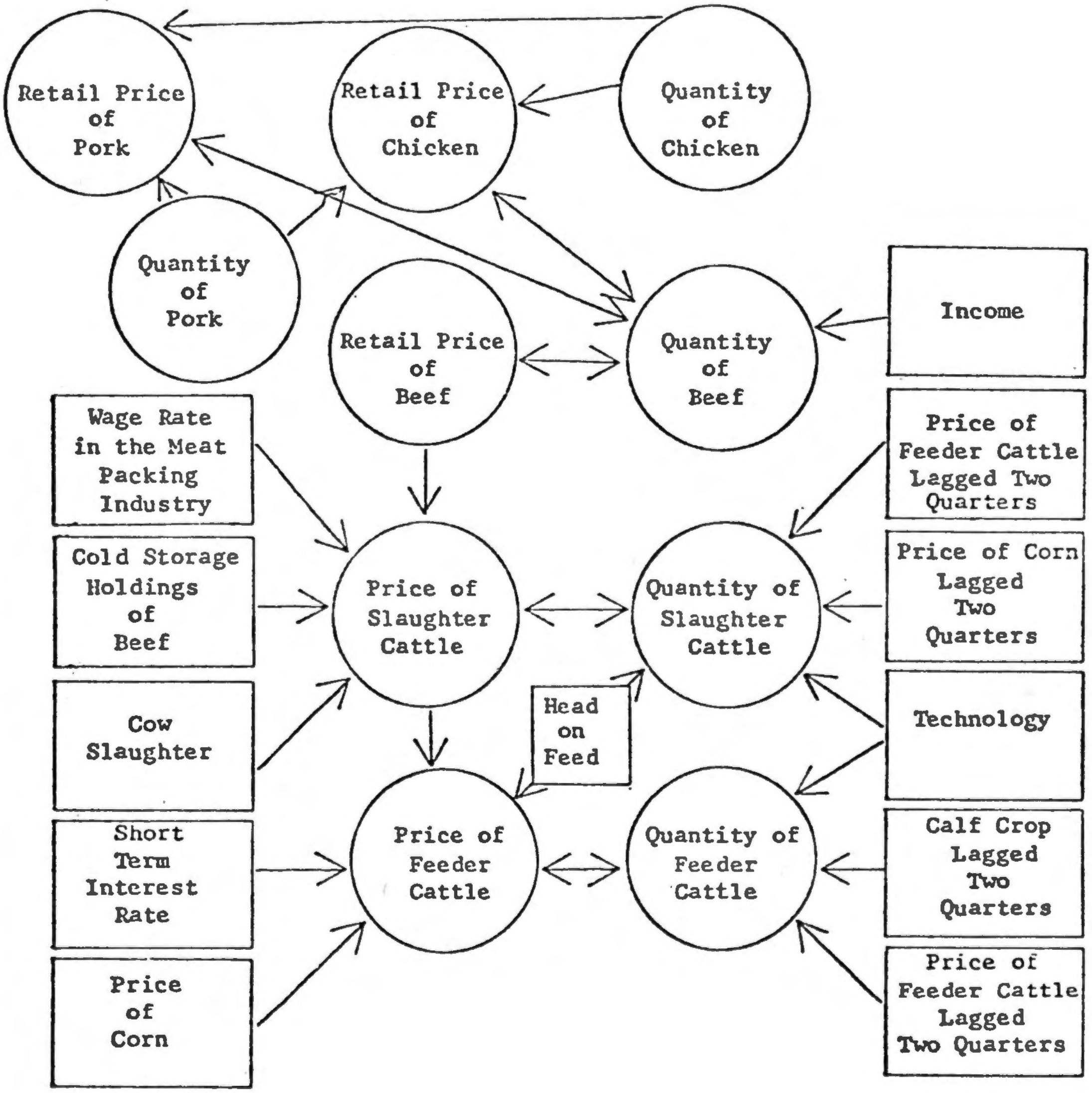

Figure 1. The major factors that enter into the demand and supply relationships for feeder cattle, slaughter cattle, and retail beef.

The formulation of the economic model consists of eight behavioral equations and two market clearing equations. The behavioral equations are normalized on the following endogenous variables:

1. Farm level price of feeder cattle.
2. Farm level quantity of feeder cattle.
3. Farm level price of slaughter cattle.
4. Farm level quantity of slaughter cattle.
5. Retail price of beef.
6. Retail quantity of beef.
7. Retail price of pork.
8. Retail price of chicken.

The complete quarterly model is presented below.

<u>Feeder Cattle Market</u>

Demand -

1. $P^*_{FC(t)} = f(Q^*_{FC(t)}, P_{C(t)}, P^*_{SC(t)}, I_{(t)}, HOF_{(t)}, M)$

Supply -

2. $Q^*_{FC(t)} = f(P^*_{FC(t)}, CC_{(t-2)}, P_{FC(t-4)}, T, M)$

Market equilibrium -

3. $Q^{S*}_{FC} = Q^{D*}_{FC}$

<u>Slaughter Cattle Market</u>

Demand -

4. $P^*_{SC(t)} = f(Q^*_{SC(t)}, P^*_{B(t)}, CI_{(t)}, WR_{(t)}, M)$

Supply -

5. $Q^*_{SC(t)} = F(P^*_{SC(t)}, P_{FC(t-2)}, P_{C(t-2)}, HOF_{(t)}, T, M)$

Market equilibrium -

6. $Q^{S*}_{SC(t)} = Q^{D*}_{SC(t)}$

Farm to Retail Marketing Margin for Beef

7. $P^*_{B(t)} = f(P^*_{SC(t)}, WR_{(t)}, Q^*_{SC(t)}, T)$

Retail Market

Demand for beef -

8. $Q^*_{B(t)} = f(P^*_{B(t)}, P^*_{P(t)}, P^*_{Ch(t)}, Y_{(t)}, M)$

Demand for pork -

9. $P^*_{P(t)} = f(Q_{P(t)}, Q_{Ch(t)}, Q^*_{B(t)}, Y_{(t)}, M)$

Demand for chicken -

10. $P^*_{Ch(t)} = f(Q_{Ch(t)}, Q^*_{B(t)}, Q_{P(t)}, Y_{(t)}, M)$

* = indicates endogenous variable.

Variables:

$P^*_{FC(t)}$ = current price of feeder cattle

$Q^*_{PC(t)}$ = current quantity of feeder cattle

$P_{C(t)}$ = current price of corn

$P^*_{SC(t)}$ = current price of slaughter cattle

$I_{(t)}$ = current short-term interest rate

$HOF_{(t)}$ = number of cattle on feed, lagged one quarter

M = quarters

$CC_{(t-2)}$ = calf crop, lagged two quarters

$Q^*_{SC(t)}$ = current quantity of slaughter cattle

$Q^*_{B(t)}$ = per capita quantity of beef consumed

$CS_{(t)}$ = beef and dairy cow slaughter

$CI_{(t)}$ = cold storage holdings of beef

$WR_{(t)}$ = current wage rate in the meat packing industry

$P_{FC(t-2)}$ = price of feeder cattle, lagged two quarters

$P_{C(t-2)}$ = price of corn, lagged two quarters

$P^*_{B(t)}$ = current retail price of beef

$P^*_{P(t)}$ = current retail price of pork

$P^*_{Ch(t)}$ = current retail price of chicken

$Y_{(t)}$ = per capita income

$Q_{P(t)}$ = per capita consumption of pork

$Q_{Ch(t)}$ = per capita consumption of chicken

T = time

The relationships for each equation are discussed in considerable detail below.

III. FARM LEVEL DEMAND RELATIONSHIP FOR FEEDER CATTLE

As a rule, feeder cattle are purchased for the purpose of further feeding in order to obtain marketable slaughter animals. As such, the demand for feeder cattle at the farm level can be considered as the demand for an input by the feedlot operator. Theoretically the firm's demand for a factor of production depends upon the price of the firm's output, prices of other factors of production, and the price of the factor under consideration.

These considerations were used to formulate the following farm level demand relationship for feeder cattle:

$$P^*_{FC(t)} = f(Q^*_{FC(t)}, P_{C(t)}, HOF_{(t)}, P^*_{SC(t)}, I_{(t)}, M)$$

where:

$P^*_{FC(t)}$ = current price of feeder cattle

$Q^{*}_{FC(t)}$ = current number of feeder cattle purchased

$P_{C(t)}$ = current price of corn

$P^{*}_{SC(t)}$ = current price of slaughter cattle

$I_{(t)}$ = current short-term interest rate

$HOF_{(t)}$ = number of cattle on feed the current quarter

M = quarters

The price of slaughter cattle represents the price of the output received by the feedlot operator. As the price of the output [$P^{*}_{SC(t)}$] increases, the price of feeder cattle [$P^{*}_{FC(t)}$] will be bid upward, ceteris paribus. Therefore, it was expected that the price of slaughter cattle will have a positive effect on the price feedlot operators are willing to pay for feeder cattle.

The price of corn [$P_{C(t)}$] and the short-term interest rate [$I_{(t)}$] represent the cost of other factors of production to the feedlot operator. The higher the costs of these factors of production, the lower will be the price feedlot operators will be willing to pay for feeder cattle. These variables were expected to have a negative influence on the price of feeder cattle.

Head on feed at the beginning of the quarter [$HOF_{(t)}$] was included to represent the capacity of feedlots and to account for part of the feedlot operators' expectations. If the number of cattle on feed in the present quarter is high, the feedlot operator would tend to bid the price of feeder cattle downward because little or no capacity is available. This suggests that head on feed will have a negative influence on the price of feeder cattle.

The quantity of feeder cattle demanded [$Q^*_{FC(t)}$] was included to account for the normal relationship between price and quantity demanded. It is expected that the quantity of feeder cattle will be inversely related to the current price of feeder cattle.

The expected direction of influence of the different quarters [M] is indeterminant, a priori.

IV. FARM LEVEL SUPPLY RELATIONSHIP FOR FEEDER CATTLE

Theory suggests that the quantity supplied of a commodity by a firm depends upon the price of the product, prices of inputs needed to produce that product, and prices of other commodities produced by that firm. The cattle industry also has some very peculiar structural aspects which should be considered in the formulation of the supply relationship.

The number of feeder cattle coming to market in the current time period (t) is not only a function of the current price but is also the result of decisions made sometime in a previous time period or quarter. The normal gestation period for cattle is around nine months. The period from birth to weaning is anywhere from six to nine months. Therefore, the number of feeder cattle available for market in a particular quarter resulted from decisions made some four to six quarters in the past.

Using these considerations, the following supply relation for feeder cattle was developed:

$$Q^*_{FC(t)} = f(P^*_{FC(t)}, CC_{(t-2)}, P_{FC(t-4)}, T, M)$$

where:

$CC_{(t-2)}$ = calf crop lagged two quarters

T = time

$Q^*_{FC(t)}$ and $P^*_{FC(t)}$ are as previously defined.

Because of the nature of the production of feeder cattle discussed above, it was decided to include a lagged price of feeder cattle. The price was lagged four quarters or one year. Thus, the number of feeder cattle supplied in any particular quarter was hypothesized to be influenced by the price of feeder cattle in that quarter one year earlier. If a favorable price of feeder cattle existed in the previous year, decisions would have been made to increase production. This increase would be available for market in the present quarter and would tend to increase the quantity supplied. Thus, the lagged price of feeder cattle [$P_{FC(t-4)}$] would be expected to have a positive influence on current supplies of feeder cattle, all other factors remaining the same.

The current price of feeder cattle [$p^*_{FC(t)}$] was included to account for the normal relationship between price and quantity supplied. It is expected that the current price of feeder cattle will have a positive influence on the quantity supplied of feeder cattle.

The calf crop lagged two quarters [$CC_{(t-2)}$] was included because the calves born approximately two quarters ago will be the animals that are marketed in the present quarter. The larger the calf crop two quarters ago, the larger the number of feeder cattle available for sale in the present quarter.

Time [T] was included to account for any technological progress that may have occurred in the production feeder cattle. The time variable could also pick up some of the influence of variables that affect quantity supplied but that were omitted from the equation. Because this variable may incorporate the influence of more than technological advances, it is difficult to determine the sign, a priori.

V. PACKER LEVEL DEMAND RELATIONSHIP FOR SLAUGHTER CATTLE

The demand relationship for slaughter cattle was formulated using the same theoretical considerations that were used in the development of the demand function for feeder cattle. The demand for slaughter cattle can be considered as the demand for an input in the meat packing industry.

The following constitutes the hypothesized demand relationship for slaughter cattle:

$$P^*_{SC(t)} = f(Q^*_{SC(t)}, P^*_{B(t)}, CS_{(t)}, CI_{(t)}, WR_{(t)}, M)$$

where:

$Q^*_{SC(t)}$ = current quantity of slaughter cattle purchased by packers

$P^*_{B(t)}$ = current retail price of beef

$CS_{(t)}$ = current cold storage holdings of beef

$WR_{(t)}$ = current wage rate in the meat packing industry

All other variables are as previously defined.

As is usual in demand analysis, it was expected that a negative relationship exists between the quantity demanded $[Q^*_{SC(t)}]$ and the price $[P^*_{SC(t)}]$.

The current retail price of beef $[p^*_{B(t)}]$ was included to account for the price of the output of the meat packing industry. As the price of the output increases, the price of slaughter cattle would tend to be bid up. Therefore, the price of retail beef was expected to have a positive influence on slaughter cattle prices.

The quantity of beef and dairy cows slaughtered [$CS_{(t)}$] was included to account for the possibility that as the number of cows slaughtered increases, the demand for slaughter beef cattle to be used in lower grade cuts should decrease. Therefore, as the number of cows slaughtered increases, the price of slaughter beef cattle [$P^*_{SC(t)}$] should decrease since cows can be considered as a partial substitute for slaughter beef cattle by packers.

Most of the cold storage holdings of beef are in the hands of the meat packers. These holdings can be used as a buffer between the amount of cattle they slaughter and the demand for beef by their customers. As cold storage holdings become too high, the packer will be less willing to purchase slaughter cattle, therefore the price of slaughter cattle would fall. Thus, cold storage holdings of beef were expected to have a negative influence on slaughter cattle prices.

The wage rate in the meat packing industry [$WR_{(t)}$] was included to account for the cost of one of the major factors of production in the meat packing industry. The higher the packers' costs, as represented by wage rates, the lower will be the price they are willing to pay for slaughter cattle.

VI. FARM LEVEL SUPPLY RELATIONSHIP FOR SLAUGHTER CATTLE

The supply relation for slaughter cattle was formulated using the theoretical supply considerations discussed earlier in this model. The supply equation for slaughter cattle was hypothesized as follows:

$$Q^*_{SC(t)} = f(P^*_{SC(t)}, P_{FC(t-2)}, P_{C(t-2)}, HOF_{(t)}, T, M)$$

where:

$P_{FC(t-2)}$ = price of feeder cattle lagged two quarters

$P_{C(t-2)}$ = price of corn lagged two quarters

All other variables are as previously defined.

The theory of supply indicates then an increase in the price of a good will cause an increase in the quantity supplied of that good, _ceteris paribus_. Thus, the current price of slaughter cattle [$P^*_{SC(t)}$] was expected to have a positive influence on the number of slaughter cattle currently available for marketing.

The price of corn lagged two quarters [$P_{C(t-2)}$] and the lagged price of feeder cattle [$P_{FC(t-2}$] were included to account for the major inputs in the production of slaughter animals.[1] As the costs of factors of production increase, the quantity supplied should decrease, _ceteris paribus_. These variables were lagged two quarters because cattle are normally kept on feed somewhere around 180 days.[2] The prices of these inputs at this time would determine in part how many calves were placed on feed and thus, the quantity of slaughter cattle coming to market in the present quarter. Therefore, these variables were expected to have a negative effect on slaughter cattle numbers.

Head on feed at the beginning of the current quarter [$HOF_{(t)}$] was included because the larger the number of cattle on feed at the beginning

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[1]The costs of other inputs, such as the price of soybean meal, were considered. However, the price of all feed stuffs tend to move together, therefore only corn was used to represent feed costs in the production of slaughter cattle.

[2]Different lags were considered, however a two quarter lag seemed to be the most appropriate.

of the quarter, the greater the quantity that could be supplied during that quarter. Therefore, head on feed was expected to have a positive influence on the quantity of feeder (SLAUGHTER) cattle.

Time [T] was included to account for any technological progress that may have occurred in the production of slaughter cattle. The time variable could also pick up some of the influence of other variables that affect quantity supplied but that were omitted from the equation.

VII. FARM TO RETAIL MARKETING MARGIN FOR BEEF

The connecting link between prices of slaughter cattle at the farm level and the retail price of beef is the farm to retail marketing margin. The marketing margin was defined as the difference between the farm level price of slaughter cattle per pound and the retail price of an equivalent amount of beef in the retail market.

Margins which appear to have an underlying structure are called "systematic" as opposed to "nonsystematic" margins which stem from oligopolistic forms of competition. For the purpose of this study, it was assumed that the farm to retail marketing margin was a "systematic" margin (Myers, Havlicek, 1970, p. 8).

It was assumed that the marketing margin for beef was not constant but was influenced by costs factors, quantities of cattle marketed, and the particular price levels. The farm to retail marketing margin for beef was formulated as follows:

$$MM^B = (P^*_{B(t)} - P^*_{SC(t)}) = f(Q^*_{SC(t)}, WR_{(t)}, P^*_{B(t)}, P^*_{SC(t)}, T)$$

where:

MM^B = farm to retail marketing margin for beef

T = time

All other variables are as previously defined.

The procedure used in this study to estimate the marketing margin for beef was to estimate a retail price equation for beef and then derive the margin from the estimated results. The estimating equation was as follows:

$$P^*_{B(t)} = f(Q^*_{SC(t)}, WR_{(t)}, P^*_{SC(t)}, T)$$

The marketing margin for beef was obtained from the equation by: (1) adjusting both sides of the equation by the net yield of the retail cuts per pound to put live prices and retail prices on a comparable basis and (2) substracting farm level prices from both sides of the equation. The resulting function pertains to the difference between the retail price of beef and the farm level price of cattle, both based on the same units.

The quantity of beef cattle marketed [$Q^*_{SC(t)}$] was included to account for variations in the marketing margin associated with varying numbers of livestock. It is widely held that in periods of short supply, the margin is small while large supplies lead to increased margins (Kohls, 1967, p. 66). Although this conclusion is widely held to be true, attempts to empirically measure the effect of quantities marketed on margins have resulted in conflicting estimates. Because of this, the sign of quantities marketed cannot be determined, _a priori_.

The wage rate in the meat packing industry [$WR_{(t)}$] was included to account for the costs associated with moving slaughter cattle from the farm and processing them into beef cuts available for consumption by consumers at the retail level. As costs increase, they are generally passed on in the form of higher prices. Thus, the wage rate in the meat packing industry is expected to have a positive influence on the marketing margin for beef.

The direction of influence of farm level price of slaughter cattle [$P^{*}_{SC(t)}$] on the marketing margin cannot be determined, a priori. A positive coefficient would indicate that packers and/or retailers were able to increase the marketing margin when the price of slaughter cattle increased. A negative coefficient would indicate that they accept smaller margins during periods of increasing prices.

The time variable [T] was included to account for any change in the marketing margin due to the passage of time. The time variable could also account for any change in the farm to retail marketing margin due to technological advancements. If technological changes have occurred which reduce the costs of packers or retailers, the time variable would have a negative influence on the marketing margin. However, if there has been an increase in the marketing margin due only to the passage of time, then the direction of influence would be determined by the relative strength of the two forces accounted for by the time variable.

VIII. RETAIL DEMAND RELATIONSHIP FOR BEEF

The theory of consumer demand is well developed and can easily be applied to the demand for retail beef. Theory suggests that the demand for a particular product is dependent upon the price (quantity) of the good, price (quantity) of substitutes and complements, income, population, and tastes and preferences.

These theoretical considerations were used in formulating the following retail demand relationship for beef:

$$Q^*_{B(t)} = f(P^*_{B(t)}, P^*_{P(t)}, P^*_{Ch(t)}, Y_{(t)}, M)$$

where:

$Q^*_{B(t)}$ = current per capita consumption of beef

$P^*_{B(t)}$ = current retail price of beef

$P^*_{P(t)}$ = current retail price of pork

$P^*_{Ch(t)}$ = current retail price of chicken

$Y_{(t)}$ = current per capita income

M = quarters

The retail price of beef [$P^*_{B(t)}$] was included to account for the normal relationship between price and quantity demanded. The retail price of beef was expected to have a negative influence on the quantity of beef demanded.

The retail prices of pork and chicken [$P^*_{P(t)}$, $P^*_{Ch(t)}$] were included to allow for the substitution of one meat for another which occurs when there is a change in the relative price structure among different meats. For the purpose of this study, pork and chicken were the only meats considered as substitutes for beef. A priori, one would expect these variables to have a positive influence on the quantity of beef consumed.

Income was included to account for the shifting of the demand relationship brought about by changes in retail purchasing power. Since beef is a normal good, then income would be expected to have a positive relationship to the quantity of beef demanded.

Quarters of the year [M] were included to account for differences in tastes and preferences insofar as they are influenced by time of the year. The expected sign of this variable is indeterminate, a priori.

Theory indicates that the current price of pork and chicken influence the current consumption of beef. However, the current price of beef also influences the consumption of pork and chicken. This indicates that the direction of causality is not one-way but both ways between quantities and prices of any combination of these three meats. Therefore, it is necessary to develop a retail demand equation for pork and chicken.

Once broilers and hogs reach market weight, they cannot be held on the farm to take advantage of future price changes. The number of hogs and broilers marketed during a given quarter is the result of decisions made some time in the past. Therefore, the number of hogs and broilers marketed and the consumption of pork and broilers during a quarter can be assumed to be predetermined in an economic sense.

IX. RETAIL PRICE EQUATION FOR PORK

Using the theoretical considerations discussed under the Retail Demand for Beef, the following retail price equation for pork was developed:

$$P^*_{P(t)} = f(Q_{P(t)}, Q_{Ch(t)}, Q^*_{B(t)}, Y_{(t)}, M)$$

where:

$Q_{P(t)}$ = current per capita consumption of pork

$Q_{Ch(t)}$ = current per capita consumption of chicken

$P^*_{P(t)}$, $Q^*_{B(t)}$, $Y_{(t)}$, M, are as previously defined.

The current per capita consumption of pork [$Q_{P(t)}$] was included to account for the normal relationship between price and quantity. It was expected that the per capita quantity will have a negative influence on the retail price of pork.

The current per capita quantities consumed of beef and chicken $[Q_{Ch(t)}, Q^*_{B(t)}]$ were included to account for the substitution of one meat for another when relative prices change. These variables were expected to have a negative influence on the price of pork.

Per capita income $[Y_{(t)}]$ was included to account for changes in the retail purchasing power of consumers. It was expected that this variable will have a positive influence on the retail price of pork.

X. RETAIL PRICE EQUATION FOR CHICKEN

The theoretical considerations concerning demand for a product discussed in the section on Retail Demand for Beef were also used to formulate the following retail price equation for chicken:

$$P^*_{Ch(t)} = f(Q_{Ch(t)}, Q^*_{B(t)}, Q_{P(t)}, Y_{(t)}, M)$$

where:

All variables are as previously defined.

The per capita quantity of chicken consumed $[Q_{ch(t)}]$ was included to account for the normal price-quantity relationship. It was expected that there would be an inverse relationship between the retail price of chicken and the per capita consumption of chicken.

The per capita consumption of beef and pork $[Q^*_{B(t)}, Q_{P(t)}]$ were included to account for the influence on price of chicken brought about through substitution of one meat for another. These variables were expected to have a positive influence on the retail price of chicken.

Per capita income was included to account for the shifting of the demand function brought about by increased purchasing power of the consumers. It was expected that this variable will have a positive influence on the retail price of chicken.

CHAPTER III

STATISTICAL MODEL AND PROCEDURES

The previous section outlined the economic model that was developed to represent the feeder cattle industry in the United States. The next step becomes one of setting these factors and relationships into a form that can be estimated with statistical methods.

I. FORM OF THE DEMAND AND SUPPLY RELATIONSHIPS

Economic theory provides little information regarding the exact mathematical form of the demand and supply relationships outlined in the preceding chapter.

The form used in this analysis was linear in the actual variates. The linear form was chosen for several reasons: (1) even if the total function is curvilinear, segments covered by this study can be approximated by a linear function; (2) it permits elasticity changes throughout the range of data; (3) previous research has shown that the linear form performs rather well (Maki 1959, Myers 1963, and Elam 1973); and (4) the computational simplicity of the form when making forecasts.

II. STATISTICAL MODEL

Economic and behavioral considerations suggest the following relationships:

1. A demand and supply relationship for feeder cattle.
2. A demand and supply relationship for slaughter cattle.
3. A farm to retail marketing margin equation.

4. A retail demand equation for beef, pork, and chicken.

Using the variables suggested by the economic model, the following statistical models represent these supply and demand relationships.

In the notation of the equation below and similar equations which follow, β denotes the coefficients to be estimated. Subscripts for the coefficients were interpreted as parameter and equation numbers. Thus, $\beta_{2.1}$ indicates the coefficients of the second variable appearing in the first equation.

<u>Statistical Demand Equation for Feeder Cattle</u>

$$P^*_{FC(t)} = \beta_{0.1} + \beta_{1.1}Q^*_{FC(t)} + \beta_{2.1}P_{C(t)} + \beta_{3.1}P^*_{SC(t)} + \beta_{4.1}I_{(t)} +$$

$$\beta_{5.1}HOF_{(t)} + \beta_{6.1}M_1 + \beta_{7.1}M_2 + \beta_{8.1}M_3 + e_1$$

<u>Statistical Supply Equation of Feeder Cattle</u>

$$Q^*_{FC(t)} = \beta_{0.2} + \beta_{1.2}P^*_{FC(t)} + \beta_{2.2}CC_{(t-2)} + \beta_{3.2}P_{FC(t-4)} + \beta_{4.2}T +$$

$$\beta_{5.2}M_1 + \beta_{6.2}M_2 + \beta_{7.2}M_3 + e_2$$

<u>Statistical Demand Equation for Slaughter Cattle</u>

$$P^*_{SC(t)} = \beta_{0.3} + \beta_{1.3}Q^*_{SC(t)} + \beta_{2.3}P^*_{B(t)} + \beta_{3.3}CS_{(t)} + \beta_{4.3}CI_{(t)} +$$

$$\beta_{5.3}WR_{(t)} + \beta_{6.3}M_1 + \beta_{7.3}M_2 + \beta_{8.3}M_3 + e_3$$

<u>Statistical Supply Equation of Slaughter Cattle</u>

$$Q^*_{SC(t)} = \beta_{0.4} + \beta_{1.4}P^*_{SC(t)} + \beta_{2.4}P_{FC(t-2)} + \beta_{3.4}P_{C(t-2)} + \beta_{4.4}HOF_{(t)} +$$

$$\beta_{5.4} + \beta_{6.4}M_1 + \beta_{7.4}M_2 + \beta_{8.4}M_3 + e_4$$

<u>Statistical Farm to Retail Marketing Margin Equations</u>

$$P^*_{B(t)} = \beta_{0.5} + \beta_{1.5}P^*_{SC(t)} + \beta_{2.5}WR_{(t)} + \beta_{3.5}Q^*_{SC(t)} + \beta_{4.5}T + e_5$$

Statistical Retail Demand Equation for Beef

$$Q^*_{B(t)} = \beta_{0.6} + \beta_{1.6}P^*_{B(t)} + \beta_{2.6}P^*_{P(t)} + \beta_{3.6}P^*_{Ch(t)} + \beta_{4.6}Y_{(t)} + \beta_{5.6}M_1 + \beta_{6.6}M_2 + \beta_{7.6}M_3 + e_6$$

Statistical Retail Demand Equation for Pork

$$P^*_{P(t)} = \beta_{0.7} + \beta_{1.7}Q_{P(t)} + \beta_{2.7}Q_{Ch(t)} + \beta_{3.7}Q^*_{B(t)} + \beta_{4.7}Y_{(t)} + \beta_{5.7}M_1 + \beta_{6.7}M_2 + \beta_{7.7}M_3 + e_7$$

Statistical Retail Demand Equation for Chicken

$$P^*_{Ch(t)} = \beta_{0.8} + \beta_{1.8}Q_{Ch(t)} + \beta_{2.8}Q^*_{B(t)} + \beta_{3.8}Q_{P(t)} + \beta_{4.8}Y_{(t)} + \beta_{5.8}M_1 + \beta_{6.8}M_2 + \beta_{7.8}M_3 + e_8$$

* = represents endogenous variables.

where:

$P^*_{FC(t)}$ = quarterly weighted average price per hundred weight [$/cwt.] of all grades of feeder steers sold out of first hands, seven markets combined (USDA Livestock and Meat Statistics, 1959-1973)

$Q^*_{FC(t)}$ = quarterly number [head] of feeder steers, all grades, sold out of first hands, seven markets combined (USDA Livestock and Meat Statistics, 1959-1973)

$P_{C(t)}$ = quarterly price per bushel [$/bushel] of No. 3 yellow corn at Chicago (USDA Feed Statistics, 1973)

$P^*_{SC(t)}$ = quarterly weighted average price per hundred weight [$/cwt.] of all weight of slaughter steers, six markets combined sold out of first hands (USDA Livestock and Meat Statistics, 1959-1973)

$I_{(t)}$ = quarterly average interest rate [%] on banker's acceptance, prime (90 days) at New York City (U. S. Department of Commerce, Survey of Current Businesses, 1959-1972)

$HOF_{(t)}$ = quarterly number [1,000 head] of cattle and calves on feed, 23 states (USDA Livestock and Meat Statistics, 1973)

M_1-M_3 = 0-1 type dummy variables for winter, summer and fall, respectively; spring was deleted to avoid singularity

e_1-e_8 = Stochastic error terms associated with each equation

$CC_{(t-2)}$ = quarterly number]1,000 head] of beef calves born on farms in the United States

$P_{FC(t-4)}$ = quarterly weighted average price per hundred weight [$/cwt.] of all grades of feeder steers sold out of first hands, seven markets combined, lagged four quarters (USDA Livestock and Meat Statistics, 1959-1973)

T = time trend, the 52 quarters of the study numbered consecutively, 1 through 52

$Q^*_{SC(t)}$ = quarterly number [head] of slaughter steers sold out of first hands, six markets combined (USDA Livestock and Meat Statistics, 1959-1973)

$P^*_{B(t)}$ = quarterly average United States retail price [¢/lb.] of beef, choice grade (USDA Livestock and Meat Statistics, 1960-1973)

$CS_{(t)}$ = quarterly number [head] of dairy and beef cows slaughtered during the present quarter (USDA Livestock and Meat Statistics, 1960-1973)

$WR_{(t)}$ = quarterly average hourly wage [$/hr.] of production workers in the meat packing industry (U. S. Department of Labor, Employment and Earning Statistics, 1960-1973)

$P_{FC(t-2)}$ = quarterly weighted average price per hundred weight [$/cwt.] of all grades of feeder steers sold out of first hands, seven markets combined, lagged two quarters (USDA Livestock and Meat Statistics, 1959-1973)

$P_{C(t-2)}$ = quarterly average price per bushel [$/bushel] of No. 3 yellow corn at Chicago, lagged two quarters (USDA Feed Statistics, 1959-1973)

$Q^*_{B(t)}$ = quarterly per capita consumption [lbs./person] of commercially produced beef in the United States (USDA Livestock and Meat Statistics, 1960-1973)

$P^*_{P(t)}$ = quarterly average retail price of pork [¢/lb.] in the United States (USDA Livestock and Meat Statistics, 1960-1973)

$P^*_{Ch(t)}$ = quarterly average retail price [¢/lb.] of frying chicken in stores in urban cities of the United States (USDA Poultry and Egg Situation, 1960-1973)

$Y_{(t)}$ = quarterly average per capita disposable income [dollars] in the United States (U. S. Department of Commerce, Business Conditions Digest, 1972-1973)

$Q_{P(t)}$ = quarterly per capita consumption [lb./person] of commercially produced pork in the United States (USDA Livestock and Meat Statistics, 1960-1973)

$Q_{Ch(t)}$ = quarterly per capita consumption [lb./person] of chicken in the United States (USDA Poultry and Egg Situation, 1960-1973)

III. METHOD OF ANALYSIS

The statistical model presented in this chapter constitutes a system of overidentified[3] simultaneous equations that represent the feeder cattle industry. There are two general classes of techniques that could be used to obtain estimates of the parameters in this system.

Single equation or multiequational methods could be used to obtain the desired estimates. The multiequation methods were eliminated because of the large sample size required and the formidable computational problems involved. The two stage least squares [TSLS][4] method was chosen from the class of single equation methods available. The TSLS method was chosen because: (1) TSLS provides consistent estimates of the parameters of a simultaneous equation system; (2) TSLS performs relatively well as compared with other methods when there is multicollinearity present; and (3) TSLS ranks highest among single equation methods in computational ease and efficiency.

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[3]For a discussion of the identification problem, see Wonnacott and Wonnacott (1970). Identification concerns whether there is sufficient information to mathematically determine a system's parameters.

[4]See Foote (1958) or Wonnacott and Wonnacott (1970) for a description of this and other methods.

The TSLS technique employs the ordinary least squares [OLS] method in both stages of the estimating procedure. As such, the normal statistical assumptions regarding this method were assumed.[5]

IV. DATA

Selection of the empirical variables to be used in estimating the parameters of the equations in the economic model was made in such a manner as to approximate as close as possible the theoretical variables specified by the economic model. Data availability, statistical limitations, and aggregation all serve to cause deviations from the theoretical specification. Even with these limitations an attempt was made to use secondary data as summarized by the U. S. Department of Agriculture (USDA) and other government agencies as much as possible. When data were not available or when data series changed, variables were constructed from existing data to conform as close as possible to theory. The derivation of data not published in a form compatible with the economic specification are discussed in this section.

The data series on price and quantity of feeder cattle as reported by the USDA did not include the same markets for each year under analysis. In order to have comparable data over the period of analysis, only the markets were used that had reported data in each year contained in the analysis. There were seven markets for which data were available for all 13 years. These markets were Kansas City, South St. Paul, Omaha, Sioux City, Oklahoma City, National Stock Yards, and South St. Joseph. The

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[5] See Kane (1968, p. 355) for a discussion of the conventional assumptions regarding the ordinary least squares technique.

weighted average price of feeder steers in these seven markets was used as the "representative" price of feeder cattle. The quantity of feeder steers sold in these seven markets was used as the quantity of feeder cattle in this study.

Data series on the price and quantity of slaughter cattle were not reported on a comparable basis for the entire period under analysis. Markets which had reported data for all years under consideration were selected to be "representative" of the price and quantity of slaughter cattle. There were six markets for which data were available for all years. These markets were Kansas City, Omaha, St. Louis, National Stock Yards, Sioux City, Sioux Falls, and South St. Joseph. The weighted average price of slaughter steers in these six markets was used as the "representative" price of slaughter cattle. The total number of slaughter steers sold in these markets was used as the quantity of slaughter cattle in this study.

The interest rate on bankers' acceptances, prime 90 days at New York City, was used as the representative short-term interest rate. This series was used because it is applicable to short periods of time, it fluctuates during short periods of time depending on short-run economic conditions, and it is readily available on a quarterly basis from the Board of Governors of the Federal Reserve System.

The quantity of pork, chicken, and beef consumed were adjusted to a per capita basis. Income was also included as a per capita value. This method alleviates the necessity of having to include population in the retail demand equations since population and income are highly correlated (Elam 1973).

The quarterly number of beef calves born on farms in the United States was not reported directly by the U.S.D.A. However, these figures were computed from the annual calf crop that was reported. The total calf crop included both dairy and beef calves, therefore these data were adjusted by the percentage of beef cows on farms January 1 of each year to all cows on farms January 1 to represent the number of beef calves born. This annual beef calf crop was then distributed equally over the four quarters of the year to represent the quarterly estimate of the number of beef calves born. The number of calves that were slaughtered and the number of calves that died were subtracted from the quarterly estimates of the beef calf crop and the result was the number of calves that were used to represent the calf crop in this study.

The means and standard deviations of all variables used in this study are presented in Table 17 of the Appendix.

V. TIME PERIOD USED IN THIS STUDY

Quarterly observations of the variables included in the economic model were obtained for the years 1960-1972. A longer period was desired however, certain changes in the reporting method of certain of the data series used necessitated the use of this period in order to have comparable data for all years. Also certain data series were not available prior to 1960.

VI. MULTICOLLINEARITY

One of the most common problems encountered when time series data are used is a high correlation among the independent variables. This correlation may occur even though the variables are not causally related but rather because each variable exhibits a simular trend over time. The problems of analyzing data which contains a high degree of multicollinearity has been discussed by several writers (Christ, 1966), (Kane, 1968), and (Foote, 1958). The major concern in this study with multicollinearity is being able to recognize the problems which occur from serious correlation among the independent variables.

Multicollinearity results in parameter estimates that are sensitive to changes in both the precise model specification and the data set employed and also result in high standard errors (Kane, 1968, p. 278) This may result in certain estimates being considered non-significant statistically when in fact they are significant.

The extreme case of perfect positive or negative correlation between two or more independent variables is easy to identify. The simple correlation coefficients are either +1 or -1 and the least squares technique breaks down because it is impossible to obtain the inverse of the (X'X) matrix. Thus, it becomes necessary to determine when the degree of multicollinearity is large enough to seriously affect the standard errors of the estimated coefficients. High correlation coefficients, values approaching ± 90 or more, are signals suggesting multicollinearity exist.

CHAPTER IV

STATISTICAL RESULTS

I. EVALUATION OF ESTIMATED COEFFICIENTS

Coefficients of the structural equations of the model were estimated using the two-stage least-squares technique (TSLS). Zero-one dummy variables were used to allow for quarterly differences in the price or quantity in all equations except the marketing margin equation.

The standard errors of structural coefficients estimated by TSLS are statistically biased and as such are referred to as asymptotic standard errors.[6] Because of this property of the standard errors, an independent variable with a coefficient at least as large as its standard error was considered to have a statistically significant influence on the dependent variable. An independent variable with a coefficient that was more than two times larger than its standard error was considered to have a highly significant influence on the dependent vatiable.

The individual coefficients were also evaluated on the basis of their conformity to their respective *a priori* hypothesized signs. These signs were determined from previously discussed economic theory and knowledge of the industry.

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[6] See Christ (1966) for a discussion of the statistical bias of the standard errors as estimated by TSLS.

II. STRUCTURAL MODEL

Demand Relationship for Feeder Cattle

Estimated coefficients of the quarterly feeder cattle demand relationship are presented in Table 1. Estimated coefficients of the quarterly intercept shifters; denoted by M_1, M_2, and M_3; refer to the difference in the price of feeder cattle between each respective quarter and the spring quarter, the omitted category. The winter quarter (M_1) included the months of January, February, and March. The spring quarter included the months of April, May, and June. The summer quarter consisted of the months of July, August, and September, while the fall quarter included the months of October, November, and December. The average feeder cattle price during the winter quarter is therefore the intercept plus the estimated coefficient of M_1, with all other variables held constant at their mean value. The price of feeder cattle was estimated to be the highest in the fall and lowest in the summer. Winter prices were also higher than spring feeder cattle prices, all other factors held constant.[7]

This estimated quarterly pattern of feeder cattle prices seemed unusual since the majority of feeder cattle came to market during the fall quarter. One possible explanation of this discrepancy lies in the seasonal pattern of placement of cattle on feed by feedlot operators. The placement of cattle on feed has historically been highest during the fall quarter of each year (Gustafson and Arsdall, 1970, p. 48). Therefore,

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[7]The <u>ceteris paribus</u> conditions were assumed in the discussion of individual coefficients throughout the remainder of this chapter.

TABLE 1. ESTIMATED STRUCTURAL COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE QUARTERLY DEMAND RELATIONSHIP FOR FEEDER CATTLE IN THE UNITED STATES, 1960-1972[a]

Explanatory Variable	Notation	Estimated Coefficient	Estimated Standard Error
Intercept		-1.793	3.2520
Winter Intercept Shifter	M_1	.03187	.57960
Summer Intercept Shifter	M_2	- .60680	.62090
Fall Intercept Shifter	M_3	.79940[b]	.74590
Quantity of Feeder Cattle	$Q^*_{FC(t)}$	- .00001948[b]	.00001241
Price of Corn	$P_{C(t)}$	- .52310	1.89300
Price of Slaughter Cattle	$P^*_{SC(t)}$	1.29400[c]	.13830
Interest Rate	$I_{(t)}$	- .10800	.18100
Head on Feed	$HOF_{(t)}$	- .0001257	.0003578

[a]The demand equation for feeder cattle was normalized on the farm level price of feeder steers ($P^*_{FC(t)}$).

[b]Indicates the absolute value of the estimated coefficient is larger than its estimated standard error.

[c]Indicates the absolute value of the estimated coefficient is more than twice as large as its estimated standard error.

during periods of declining supplies of feeder cattle, as was experienced during the years covered in this study, the price of feeder cattle may be bid upward. This upward pressure on prices could result from the composition of farmer feeders, commercial feeders, and custom feeders for a limited quantity of feeder cattle in order to keep their operation at full capacity.

The quantity of feeder cattle demanded [$Q^{*}_{FC(t)}$] had a significantly negative effect upon the price of feeder cattle. This was in accordance with the a priori expectation discussed in the section dealing with the economic model. The estimated coefficient was larger than the estimated standard error indicating a statistically significant effect upon the price of feeder cattle. The quantity of feeder cattle was measured in head, therefore the estimated coefficient indicated that a 10,000 head increase in the number of feeder cattle demanded would decrease the price of feeder cattle $0.19 per hundredweight.

The price of corn [$P_{C(t)}$] was inversely related to the price of feeder cattle. This was as expected, a priori, however the estimated coefficient was smaller than the standard error. This indicated that the price of corn did not appear to have a statistically significant impact on feeder cattle prices.

The price of slaughter cattle [$P^{*}_{SC(t)}$] was found to have a significantly positive effect upon the price of feeder cattle in the United States. The estimated coefficient was more than nine times as large as the standard error. An increase of one dollar in the price per hundredweight of slaughter cattle increased the price paid for feeder cattle by $1.29 per hundredweight.

The estimated coefficient of the short term interest rate [$I_{(t)}$] had a negative sign as was hypothesized in the economic model. The standard error, however, was larger than the estimated coefficient indicating that interest rates were not statistically related to feeder cattle prices.

The number of cattle and calves on feed at the beginning of each quarter [$HOF_{(t)}$] had a negative relationship to the price of feeder cattle. This was as expected a priori, however, the estimated coefficient was smaller than the estimated standard error.

Supply Relationship for Feeder Cattle

Estimated coefficients and standard errors of the variables included in the quarterly supply relationship for feeder cattle are presented in Table 2. The quantity of feeder cattle supplied was significantly higher in the fall and summer as compared to the spring quarter. The winter quarter supply was below the spring quarter level but this difference was not significant.

This particular pattern was a result of the production pattern of feeder cattle. Most of the calves are dropped in the spring and are then ready for market in the fall. Calves born in the fall are usually marketed in the spring or summer of the following year.

The price of feeder cattle [$P^*_{FC(t)}$] had a significantly positive effect upon the quantity of feeder cattle supplied. The estimated coefficient was larger than the standard error. The estimated coefficient indicated that a one dollar increase in the price per hundredweight of feeder cattle would result in an increase of 2143 head in the quantity supplied.

TABLE 2. ESTIMATED STRUCTURAL COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE QUARTERLY SUPPLY RELATIONSHIP FOR FEEDER CATTLE IN THE UNITED STATES, 1960-1972[a]

Explanatory Variable	Notation	Estimated Coefficient	Estimated Standard Error
Intercept		33280.00	109300.00
Winter Intercept Shifter	M_1	- 9564.00	11030.00
Summer Intercept Shifter	M_2	25620.00[c]	12540.00
Fall Intercept Shifter	M_3	58870.00[c]	13150.00
Price of Feeder Cattle	$P^*_{FC(t)}$	2143.00[b]	1867.00
Calf Crop (Lagged two Quarters)	$CC_{(t-2)}$	26.08	28.49
Price of Feeder Cattle (Lagged four Quarters)	$P_{FC(t-4)}$	1346.00	1872.00
Time	T	- 3603.00[b]	2009.00

[a]The supply equation for feeder cattle was normalized on the farm level quantity of feeder steers ($Q^*_{FC(t)}$).

[b]Indicates the absolute value of the estimated coefficient is larger than its estimated standard error.

[c]Indicates the absolute value of the estimated coefficient is more than twice as large as its estimated standard error.

The above relationships indicated that the quantity of feeder cattle supplied to the market within a given quarter was in part determined by the quarterly price of feeder cattle. Also, the quantity of feeder cattle demanded during a quarter was found to influence the quarterly price of feeder cattle in the demand function discussed in the previous section. These findings tend to support the hypothesis that the price and quantity of feeder cattle are simultaneously determined during a given quarter.

The estimated coefficient for calf crop lagged two quarters [$CC_{(t-2)}$] conformed to a priori expectations with respect to sign; however, the estimated standard error was larger than the coefficient. It should be noted that calf crop was highly correlated with time as indicated by a correlation coefficient of over .98. Therefore, the separate effect of these two variables on the supply of feeder cattle could not be determined. The correlation coefficients between all independent variables used in this study are presented in Table 18 of the Appendix.

The lagged price of feeder cattle [$P_{FC(t-4)}$] resulted in an estimated coefficient of 1346. This indicated that a one dollar increase in the price of feeder cattle during the same quarter in the preceding year would result in an increase in the quarterly quantity supplied in the present year by 1346 head. However, the estimated coefficient was smaller than the standard error indicating that the lagged price did not influence the present quarterly supply of feeder cattle as much as the current quarterly price of feeder cattle. This reinforces the simultaneous nature of the feeder cattle sector as hypothesized by the economic model.

The time variable [T] had a significantly negative influence on the quantity of feeder cattle supplied. The estimated coefficient indicated there had been a 3603 head decrease quarterly in the quantity supplied over the time period used in this study. Examination of the levels of quantity supplied over time indicated that the time period chosen for this study was in part a down swing in the feeder cattle cycle. As was mentioned earlier, time was highly correlated with the calf crop in this equation. This high correlation prohibits the separation of the true effect of time on the quantity supplied.

Demand Relationship for Slaughter Cattle

The estimated coefficients and standard errors for the variables included in the demand relationship for slaughter cattler are presented in Table 3. The price of slaughter cattle during the winter quarter was above the spring quarter. The summer and fall quarter prices were below the spring quarter level. However, the fall quarter intercept shifter was the only shifter with a coefficient larger than its standard error. This indicated that fall quarter prices of slaughter cattle were significantly lower than spring quarter prices.

The quantity of slaughter cattle [$Q^*_{SC(t)}$] was found to have a negative influence on the price of slaughter cattle. This was as expected *a priori*, however, the standard error was larger than the estimated coefficient indicating that the quantity of slaughter cattle marketed during a given quarter had little statistical impact on quarterly slaughter cattle prices.

The retail price of beef [$P^*_B(t)$] was found to have a significantly positive effect on the price of slaughter cattle. The estimated

TABLE 3. ESTIMATED STRUCTURAL COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE QUARTERLY DEMAND RELATIONSHIP FOR SLAUGHTER CATTLE IN THE UNITED STATES, 1960-1972[a]

Explanatory Variable	Notation	Estimated Coefficient	Estimated Standard Error
Intercept		-1.56900	5.7350
Winter Intercept Shifter	M_1	.01236	.37600
Summer Intercept Shifter	M_2	- .20280	.37590
Fall Intercept Shifter	M_3	- .43820[b]	.39830
Quantity of Slaughter Cattle	$Q^*_{SC(t)}$	- .000001078	.000003207
Price of Retail Beef	$P^*_{B(t)}$	.32060[c]	.00723
Cold Storage Holdings of Beef	$CI_{(t)}$	- .00001295[c]	.000004832
Cow Slaughter	$CS_{(t)}$	.00152[c]	.00070
Wage Rate in Meat Packing Ind.	$WR_{(t)}$	.52300	1.79000

[a]The demand equation for slaughter cattle was normalized on the farm level price of slaughter steers ($P^*_{SC(t)}$).

[b]Indicates the absolute value of the estimated coefficient is larger than its estimated standard error.

[c]Indicates the absolute value of the estimated coefficient is more than twice as large as its estimated standard error.

coefficient was over 44 times greater than the estimated standard error, suggesting highly significant statistical relationship between the retail price of beef and the quarterly price of slaughter cattle. The direction of influence was as expected from economic theory.

The cold storage holdings of beef [$CI_{(t)}$] were found to have a negative influence on the price of slaughter cattle. The estimated coefficient was more than two times larger than the estimated standard error. This indicated that cold storage holdings of beef by processors had a highly significant statistical effect on the price paid for slaughter cattle. The negative relationship was as hypothesized in the economic model.

The number of cows slaughtered [$CS_{(t)}$] each quarter was found to have a significantly positive effect on the price of slaughter cattle. The estimated coefficient was more than two times larger than its standard error. It was hypothesized that a negative relationship sould exist between cow slaughter and the price of slaughter cattle; however, the estimated coefficient carried a positive sign. This positive sign could possibly be a result of dairy farmers and other producers selling cull cows during periods of high slaughter cattle prices, however, such increases in cull cow numbers did not appear large enough to reduce high slaughter cattle prices.

The wage rate in the meat packing industry [$WR_{(t)}$] was found to have a positive effect on the price of slaughter cattle. It was hypothesized <u>a priori</u> that a negative relationship would exist between these two variables. However, the estimated coefficient was smaller than the standard error. Also, cow slaughter was highly correlated (.77) with the wage rate. This would tend to conceal the pure effect of the wage rate on the price of slaughter cattle.

Supply Relationship for Slaughter Cattle

The estimated coefficients and standard errors of the variables included in the quarterly supply relationship for slaughter cattle are presented in Table 4. The quantity of slaughter cattle supplied was found to be significantly lower in the winter, summer, and fall than in the spring. The estimated coefficient for winter was more than two times greater than its standard error while the coefficients for summer and fall were at least as large as their respective standard errors.

The current price of slaughter cattle was found to have a significantly negative influence on the quarterly quantity of slaughter cattle supplied. The estimated coefficient was more than two times larger than the standard error. The direction of influence was opposite to that which was hypothesized in the economic model.

Myers (1970) observed a similar negative price-quantity relationship when studying the supply of slaughter cattle as it related to the hog-pork sector. He interpreted this as indicating that since current prices are a component of expected prices producers respond more to expected prices than to current prices. If this is true, then during periods of relatively high prices a producer may hold cattle from the market because his expectations the next quarter are higher than the current price. The opposite would occur during periods of low prices.

The price of feeder cattle lagged two quarters [$P_{FC(t-2)}$] was found to have a significantly negative influence on the quantity of slaughter

TABLE 4. ESTIMATED STRUCTURAL COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE QUARTERLY SUPPLY RELATIONSHIP FOR SLAUGHTER CATTLE IN THE UNITED STATES, 1960-1972[a]

Explanatory Variable	Notation	Estimated Coefficient	Estimated Standard Error
Intercept		1250000.00[c]	203000.00
Winter Intercept Shifter	M_1	- 54030.00[c]	26740.00
Summer Intercept Shifter	M_2	- 53110.00[b]	36800.00
Fall Intercept Shifter	M_3	- 62960.00[b]	47060.00
Price of Slaughter Cattle	$P^*_{SC(t)}$	- 17720.00[c]	4253.00
Price of Feeder Cattle (Lagged two Quarters)	$P_{FC(t-2)}$	- 4920.00[b]	3710.00
Price of Corn (Lagged two Quarters)	$P_{C(t-2)}$	45050.00	62300.00
Head on Feed	$HOF_{(t)}$	2.77	27.19
Time	T	- 6165.00[b]	3600.00

[a]The supply equation for slaughter cattle was normalized on the farm level quantity of slaughter steers ($Q^*_{SC(t)}$).

[b]Indicates the absolute value of the estimated coefficient is larger than its estimated standard error.

[c]Indicates the absolute value of the estimated coefficient is more than twice as large as its estimated standard error.

cattle supplied. This was as expected based upon the economic reasoning used in the economic model. The estimated coefficient was larger than the standard error.

The price of corn lagged two quarters [$P_{C(t-2)}$] was found to have a positive effect on the quantity of slaughter cattle supplied. This was opposite to what was expected a priori, however, the estimated coefficient was smaller than the standard error. This indicated that the lagged price of corn did not appear to have a statistical impact on the current quantity of slaughter cattle supplied.

Head on feed [$HOF_{(t)}$] at the beginning of each quarter had a positive effect on the quantity of slaughter cattle supplied. This agreed with the a priori expectation regarding sign, however, the estimated coefficient was smaller than the standard error indicating that the head of cattle on feed did not have a statistically significant impact on the quantity of slaughter cattle supplied.

The estimated coefficient for time was negative and indicated that the quantity of slaughter cattle supplied had decreased 6165 head quarterly over the time period covered by this study assuming that all other variables included in the equation are held constant. Examination of the quantity of slaughter cattle supplied over time indicated that the particular years covered by this study were actually part of a downswing and trough in the cattle cycle. This was consistent with the time variable in the supply function for feeder cattle. Also, it should be noted that time was highly correlated with head on feed in this equation as indicated by the correlation coefficient of .89. Thus, making separate interpretation of these two variables difficult.

Farm to Retail Marketing Margin for Beef

The coefficients and standard errors of the estimating equation for the farm to retail beef margin are presented in Table 5. All estimated coefficients were larger than their respective standard errors.

Since slaughter cattle prices [$P^*_{SC(t)}$] are on a liveweight basis, and retail prices [$P^*_{B(t)}$] are on a retail cut basis, the derivation of the farm to retail margin included an adjustment of the coefficients of the estimated equation. The coefficients of the variables on the right hand side of the estimated equation were multiplied by .472. The price of slaughter cattle was then subtracted from both sides of the equation resulting in the marketing margin for beef shown below:[8]

$$MM^B = (P^*_{B(t)} - P^*_{SC(t)}) = 5.626 - .391\ P^*_{SC(t)}$$

$$+ 7.40\ WR_{(t)} - .000003151\ Q^*_{SC(t)}$$

$$- .1188\ T$$

The above equation suggests that an increase in the current price of slaughter cattle will lead to a reduction in the marketing margin for beef. This was as expected a priori since during short run periods of rising prices marketing margins tend to be reduced [Kohls, 1967, p. 66].

The wage rate in the meat packing industry [$WR_{(t)}$] was found to have a positive effect on the marketing margin for beef. This agreed with a priori expectations with regard to sign.

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[8] Adjustment coefficient was derived as follows: carcass yields average 59 pounds per 100 pounds liveweight. Retail cuts average 80 pounds per 100 pounds of carcass weight, therefore net yield of retail beef per pound of liveweight is approximately 47.2%. (U.S.D.A. 1956, p. 14).

TABLE 5. ESTIMATED STRUCTURAL COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE FARM TO RETAIL MARKETING MARGIN FOR BEEF, 1960-1972[a]

Explanatory Variable	Notation	Estimated Coefficient	Estimated Standard Error
Intercept		11.920[b]	6.5110
Price of Slaughter Cattle	$P^*_{SC(t)}$	1.290[c]	.1831
Wage Rate In Meat Packing Ind.	$WR_{(t)}$	15.680[c]	1.8460
Quantity of Slaughter Cattle	$Q^*_{SC(t)}$	- .000006675[b]	.000004552
Time	T	- .2518[c]	.04959

[a]The farm to retail marketing margin equation was normalized on the retail price of beef ($P^*_{B(t)}$).

[b]Indicates the absolute value of the estimated coefficient is larger than its estimated standard error.

[c]Indicates the absolute value of the estimated coefficient is more than twice as large as its estimated standard error.

The marketing margin was found to decrease with an increase in the quantity of slaughter cattle [$Q^*_{SC(t)}$] moving through the market. No hypothesis was made a priori regarding the sign associated with this variable since different studies have arrived at different conclusions.

The marketing margin was found to have decreased over the study period as indicated by the negative sign of the estimated coefficient for time [T]. This variable could have captured the influence of any technological change which reduced costs and thus the marketing margin that may have occurred over the past years. The time variable could also have picked up the influence of any variables which are highly correlated with time but were excluded from the equation.

Retail Demand Relationship for Beef

Estimated coefficients and standard errors for the variables included in the demand relationship for beef are presented in Table 6.

Retail demand for beef was found to be highest in the summer quarter followed by the spring quarter. The quantity demanded was found to be lowest in the winter and fall quarters. The coefficient for summer was found to be more than twice as large as its standard error, while the winter shifter was larger than its standard error.

Quarterly per capita quantities of beef demanded responded negatively to the current quarterly price of retail beef [$P^*_{B(t)}$]. The coefficient indicated that a one cent increase in the retail price of beef resulted in approximately a .2 pound decrease in the per capita demand for beef. This agreed with the a priori hypothesis regarding the direction of influence. The estimated coefficient was more than two times

TABLE 6. ESTIMATED STRUCTURAL COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE QUARTERLY RETAIL DEMAND RELATIONSHIP FOR BEEF IN THE UNITED STATES, 1960-1972[a]

Explanatory Variable	Notation	Estimated Coefficient	Estimated Standard Error
Intercept		18.9500[c]	1.8580
Winter Intercept Shifter	M_1	- .2529[b]	.1861
Summer Intercept Shifter	M_2	.9393[c]	.1922
Fall Intercept Shifter	M_3	- .0510	.1961
Retail Price of Beef	$P^*_{B(t)}$	- .2078[c]	.0231
Retail Price of Pork	$P^*_{P(t)}$	.02114[b]	.0157
Retail Price of Chicken	$P^*_{CH(t)}$	.07205[b]	.0653
Income	$Y_{(t)}$	.02978[b]	.0019

[a]The demand equation for retail beef was normalized on the per capita quantity of beef consumed in the United States ($Q^*_{B(t)}$).

[b]Indicates the absolute value of the estimated coefficient is larger than its estimated standard error.

[c]Indicates the absolute value of the estimated coefficient is more than twice as large as its estimated standard error.

larger than the standard error indicating that the quarterly retail price of beef had a statistically significant impact on the quarterly quantity of beef demanded per capita.

The signs of the retail price of pork $[P^*_{P(t)}]$ and the retail price of chicken $[P^*_{CH(t)}]$ were both expected to be positive a priori, since these two meats are considered substitutes for beef. The estimated coefficients conformed to the a priori expectations regarding the direction of influence. The estimated coefficient for the retail price of pork was .2114 indicating that a one cent increase in the price of pork would result in a .2114 pound increase in the per capita quantity of beef demanded. The estimated coefficient for chicken indicated that a one cent increase in the price of chicken per pound would increase the per capita consumption of beef .7205 pounds. Both coefficients were larger than their respective standard errors.

As expected, income $[Y_{(t)}]$ had a positive relationship to the quantity of beef demanded per capita. The coefficient indicated that an increase of one dollar in the per capita disposable income would increase the quantity of beef demanded by .30 pounds per capita. The estimated coefficient was larger than the standard error indicating that income was a statistically significant variable affecting the level of beef demanded.

Retail Demand Relationship for Pork

The retail demand relationship for pork was normalized on the retail price of pork since the quantity of pork was assumed to be predetermined during any one quarter. The estimated coefficients and their standard errors are presented in Table 7.

TABLE 7. ESTIMATED STRUCTURAL COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE QUARTERLY RETAIL DEMAND RELATIONSHIP FOR PORK IN THE UNITED STATES, 1960-1972[a]

Explanatory Variable	Notation	Estimated Coefficient	Estimated Standard Error
Intercept		96.9800[c]	7.4970
Winter Intercept Shifter	M_1	6.7830[6]	1.4430
Summer Intercept Shifter	M_2	2.8390[c]	.8980
Fall Intercept Shifter	M_3	10.4600[c]	1.3790
Quantity of Pork	$Q_{P(t)}$	- 4.9310[c]	.3702
Quantity of Chicken	$Q_{CH(t)}$	3.0540[c]	1.2840
Quantity of Beef	$Q_{B(t)}$	- 1.2360[c]	.4609
Income	$Y_{(t)}$	.07337[c]	.0091

[a]The demand equation for retail pork was normalized on the retail price of pork consumed in the United States ($P^*_{P(t)}$).

[b]Indicates the absolute value of the estimated coefficient is larger than its estimated standard error.

[c]Indicates the absolute value of the estimated coefficients is more than twice as large as its estimated standard error.

The demand functions for pork in the winter, summer, and fall quarters were found to be significantly higher than the spring quarter. Fall was the highest, followed by winter then summer, and finally spring. All coefficients were at least two times as large as their standard errors.

The quantity of pork [$Q_{P(t)}$] was found to have a negative influence on the retail price of pork. This conformed to the *a priori* expectations regarding the economic behavior of these two variables. The estimated coefficient was also more than two times larger than the standard error.

The quantity of chicken [$Q_{CH(t)}$] and the quantity of beef [$Q^*_{B(t)}$] were included to account for substitute meats. As such, these variables were expected to have a negative influence on the price of pork. The quantity of beef conformed to the *a priori* expectations, however the quantity of chicken had a positive sign. These signs indicated that beef was a substitute for pork, while chicken appeared to be a complement. The positive sign for chicken could possibly be caused by the fact that the quantity of chicken was highly correlated (.90) with income in this equation. The estimated coefficients of both the quantity of chicken and the quantity of beef were more than twice as large as their respective standard errors. This indicated that the quantity of chicken and beef had a statistically significant impact on the retail price of pork.

Income [$Y_{(t)}$] had a positive influence on the price of pork, which was as hypothesized. The estimated coefficient was also more than two times larger than its standard error. As mentioned above, income was found to be highly correlated (.90) with the quantity of chicken in this equation, which tends to conceal the pure effect of income on the retail price of pork.

Retail Demand Relationship for Chicken

Estimated coefficients and standard errors for the variables included in the quarterly retail demand for chicken are presented in Table 8. The level of demand was found to be highest in the summer quarter, followed by spring quarter with winter and fall quarters displaying the lowest level of demand. The coefficient of the summer intercept shifter was the only one larger than its standard error.

As expected, the quantity of chicken [$Q_{CH(t)}$] was found to have an inverse relationship with the price of chicken. However, the estimated coefficient was smaller than the standard error. As mentioned earlier, the quantity of chicken was highly correlated with income ($r = .90$), which could account for the non-significant effect of quantity on the price of retail chicken in this equation.

The quantity of beef [$Q^*_{B(t)}$] was found to have a negative influence on the retail price of chicken. This was as expected since beef and chicken are considered as substitutes in the American diet. The estimated coefficient for the quantity of beef indicated that a one pound increase in the quarterly per capita consumption of beef would result in a .81 cent per pound decrease in the retail price of chicken. The estimated coefficient for the quantity of beef was more than two times larger than its standard error indicating a statistically significant impact of beef on the retail price of chicken.

The quantity of pork [$Q_{P(t)}$] was also found to have a negative influence on the price of chicken. This was as expected since pork and chicken were hypothesized to be substitute goods. The estimated coefficient indicated that a one pound increase in the per capita consumption

TABLE 8. ESTIMATED STRUCTURAL COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE QUARTERLY RETAIL DEMAND RELATIONSHIP FOR CHICKEN IN THE UNITED STATES, 1960-1972[a]

Explanatory Variable	Notation	Estimated Coefficient	Estimated Standard Error
Intercept		56.5300[c]	6.0270
Winter Intercept Shifter	M_1	- .3730	1.1600
Summer Intercept Shifter	M_2	1.0040[b]	.7219
Fall Intercept Shifter	M_3	- 1.0110	1.1080
Quantity of Chicken	$Q_{CH(t)}$	- .7214	1.0320
Quantity of Beef	$Q_{B(t)}$	- .8091[c]	.3705
Quantity of Pork	$Q_{P(t)}$	- .4057[b]	.2976
Income	$Y_{(t)}$	.0241[c]	.0073

[a]The demand equation for chicken was normalized on the retail price of chicken in the United States ($P^*_{CH(t)}$).

[b]Indicates the absolute value of the estimated coefficient is larger than its estimated standard error.

[c]Indicates the absolute value of the estimated coefficient is more than twice as large as its estimated standard error.

of pork would result in a .41 cents decrease in the retail price of chicken. The estimated coefficient was greater than its standard error.

Income had a significantly positive effect on the retail price of chicken, indicating that chicken was a normal good. The estimated coefficient was more than two times larger than its standard error. The coefficient indicated that a one dollar increase in per capita disposable income would result in a .02 cent per pound increase in the retail price of chicken.

III. ELASTICITIES, CROSS-ELASTICITIES, AND FLEXIBILITIES

Price elasticities, cross-elasticities and flexibilities may be derived from the coefficients presented in the previous section. However, these estimates need to be interpreted with caution. First, the derived estimates are dependent upon the particular values used for the variables involved. Second, the _ceteris paribus_ condition assumed when talking of elasticities and flexibilities do not hold for systems of simultaneous equations.

Estimates of elasticities and flexibilities presented in this section should be viewed as approximations since they hold only under the _ceteris paribus_ conditions with regard to the other prices and quantities. These approximations are, however, useful in terms of giving some insight into the relative responsiveness of selected variables to relative changes in the other variables.

The elasticities and flexibilities estimated from the structural model are presented in Table 9. The means of the data used in this study from which these elasticities and flexibilities were computed are given in Table 17 of the Appendix.

TABLE 9. ELASTICITIES, FLEXIBILITIES, AND PRICE REACTION COEFFICIENTS OF THE BEHAVIORAL RELATIONSHIPS OF THE QUARTERLY STRUCTURAL MODEL, 1960-1972

Dependent Variable	Price Elasticities and Flexibilities of Demand	Price Elasticity of Supply	Cross Price Elasticities and Flexibilities of Demand With Respect to			Income Elasticity and Flexibility	Price Reaction With Respect to	
			Beef	Pork	Chicken		P_{sc}	P_b
P_{FC}	-0.15[a]	-	-	-	-	-	1.03[c]	-
Q_{FC}	-	0.28[b]	-	-	-	-	-	-
P_{SC}	-0.02[a]	-	-	-	-	-	-	1.07[c]
Q_{SC}	-	-0.88[b]	-	-	-	-	-	-
Q_B	-0.72[b]	-	-	0.06[b]	0.12[b]	0.79[b]	-	-
P_P	-1.16[a]	-	-0.45[a]	-	0.36[a]	0.74[a]	-	-
P_{CH}	-0.14[a]	-	-0.51[a]	-0.16[a]	-	0.40[a]	-	-

[a]Price flexibility was defined as the estimated percentage change in market price associated with a percentage change in a quantity variable.

[b]Price elasticity was defined as the estimated percentage change in quantity associated with a percentage change in market price.

[c]Price reaction was defined as the percentage change in the market price of a product associated with a percentage change in another price variable.

The estimated farm level price flexibility of demand for feeder cattle in this study was -.15.[9] This estimate was obtained using the mean values of price and quantity for all 52 observations used in this study. This estimate indicated that a one percent increase in the quantity of feeder cattle would decrease the price of feeder cattle by .15 percent.

The price flexibility of demand for slaughter cattle was -.02, indicating that a one percent change in the quantity of slaughter cattle results in a .02 percent change in the price of slaughter cattle in the opposite direction.

The price flexibility in the slaughter cattle market was smaller in absolute value than the flexibility in the feeder cattle market. Since both price and quantity in both sectors were simultaneously determined in this model, indications are that a one percent change in cattle numbers has a greater influence in the feeder cattle market than in the slaughter cattle market. This indicates that the simultaneity in the feeder cattle sector is stronger than the simultaneity in the slaughter cattle sector.

The price elasticity of supply for feeder cattle was found to be .28.[10] Thus, a one percent change in the price of feeder cattle resulted in a .28 percent change in the quantity supplied in the same direction.

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[9]Price flexibility was defined as the estimated percentage change in market price associated with a percentage change in a quantity variable. The computational formula was: $\underline{F} = \partial P/\partial Q \cdot \overline{Q}/\overline{P}$ where $\partial P/\partial Q$ was the estimated coefficient and $\overline{P}$ and $\overline{Q}$ were the mean values.

[10]The elasticity of supply was defined as the percentage change in quantity supplied associated with a percentage change in the market price.

The price elasticity of supply in the slaughter cattle sector was -.88 for this study. This indicated a .88 percent decrease in quantity of slaughter cattle supplied for every one percent increase in price.

Elasticities computed from the retail demand equation for beef and the flexibilities computed from the retail demand equations for pork and chicken are presented in Table 9. Since the retail demand equation for beef was normalized on the quantity of beef while the demand equations for pork and chicken were normalized on their respective prices, elasticities and flexibilities derived from these estimated equations cannot be directly compared.

The price elasticity of demand for beef at the retail level was -.72 at the means of the data used in this study.[11] These results indicated that a one percent increase in the retail price of beef would tend to reduce the quantity of beef demanded by .72 percent. The cross-price elasticity of demand for beef with respect to pork was .06 and .12 with respect to chicken. This indicated that a one percent increase in the retail price of pork would result in a .06 percent increase in the per capita consumption of beef, while a one percent increase in the retail price of chicken would result in a .12 percent increase in the per capita consumption of beef.

The income elasticity for beef was .79. This indicated that there is an inelastic response in the quantity of beef demanded to changes in per capita disposable income.

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[11]The price elasticity of demand was defined as the estimated percentage change in quantity associated with a percentage change in the market price. The computational formula was: $E = \partial Q/\partial P \cdot \overline{P}/\overline{Q}$, where $\partial Q/\partial P$ was the estimated coefficient and $\overline{P}$ and $\overline{Q}$ are the mean values.

The price flexibility of demand for pork was found to be -1.16, indicating that a one percent increase in the quantity of pork resulted in a 1.16 percent decrease in the retail price of pork. The price flexibility of the retail demand for chicken was found to be -.14. Thus quantity fluctuations of pork at the retail level caused greater price responses than fluctuations in the quantity of chicken.

Houck (1965) showed that the reciprocal of estimated flexibilities formed the lower limit of direct price elasticities assuming that there were no substitution and complementary effects within the equation from which the flexibility was estimated. For this study the reciprocal of the estimated price flexibility for pork indicated an approximation of the price elasticity of demand for pork of -.86. The reciprocal of the price flexibility of chicken indicated an approximation of the price elasticity for chicken of -7.14.

The cross-price flexibility of pork with respect to beef and the cross price flexibility of chicken with respect to beef were -.45 and -.51 respectively. These results indicated that an increase of one percent in the quantity of beef consumed per capita affected the price of chicken more than the price of pork. Thus there may be a slightly stronger substitute relationship between chicken and beef than between pork and beef. The reciprocal of these cross-price flexibilities yielded approximations of the cross-price elasticity of demand for pork and chicken with respect to beef of -2.22 and -1.96 respectively.

The income flexibility of demand for pork was .74 while the income flexibility of demand for chicken was .40. This indicated that increases in per capita disposable income tended to shift the demand function for pork relatively more than the demand function for chicken.

A price reaction estimate was made between the price of feeder cattle and the price of slaughter cattle, and also between the price of slaughter cattle and the retail price of beef.[12] The estimates were 1.03 between the price of feeder cattle and slaughter cattle prices and 1.07 between slaughter cattle prices and the retail price of beef. These results indicated that as slaughter cattle prices increased feeder cattle prices increased proportionally more in percentage terms. Also increases in the retail price of beef lead to a larger percentage increase in the price paid for slaughter cattle. Thus indicating that feedlot operators and packers tended to bid up the price of feeder cattle and slaughter cattle, which are major inputs in their operation, proportionally more than the increase in the price of their output during periods of rising prices. The opposite would occur during periods of falling prices.

IV. SHORT-RUN FORECASTING

The complete structural model discussed above involved the feeder cattle, slaughter cattle, and retail sectors of the beef industry. However, since the major emphasis of this study was focused on the feeder cattle sector, forecasting models developed in this section are only for this sector of the beef cattle economy. This in no way inhibits the

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[12]Price reaction was defined as the percentage change in the market price of a particular product associated with a percentage change in another price variable.

possibility of using the structural model for forecasting prices and quantities in the slaughter cattle or retail sectors.

Forecasts of quarterly adjustments in price and quantity of feeder cattle in the United States could serve to reduce the uncertainties in the decision making process at the farm level and throughout the marketing channel. These forecasts could be useful in planning production and marketing at various levels in the beef cattle economy.

This section is concerned with the development of predictive models for the price and quantity of feeder cattle. Several models were developed from the structural relationships estimated in the previous sections. The predictive powers of these models were evaluated using all data from 1960 to 1972 for Model I. The first five quarters following this period was used to evaluate all models which are modifications of Model I.

Predictive Model I

Model I was developed using the equations of the first stage of the two-stage least-squares technique. The equations considered in this study consisted of making feeder cattle prices and quantities a function of all exogenous variables in the system. The coefficients and standard errors of the variables included in Model I are presented in Table 20 of the Appendix.

The first evaluation of the predictive power of Model I was to use the model to predict the values of the price and quantity of feeder cattle over the 52 observations used in this study. The predicted values, actual values, and deviations between actual and predicted values for the price and quantity of feeder cattle are presented in Table 19 of the Appendix. The predicted and actual values of the price and quantity of feeder cattle were plotted against time and presented in Figure 2 and Figure 3, respectively.

Observation of the actual and predicted values of the price and quantity of feeder cattle presented in Figure 2 and Figure 3 indicated that Model I correctly predicted 38 out of 52 directions of change for price and 42 out of the 52 directions of change for quantity. However, the true test of a forecasting model is not necessarily how well it predicts price and quantity data which was used to estimate the model but how well it can predict price and quantity data which occurred after the period used to estimate the model.

Model I was used to predict the price and quantity of feeder cattle in the United States for the four quarters of 1973 and the first quarter of 1974. The predicted values of the price and quantity of feeder cattle along with the actual values are presented in Table 10.

This model underestimated the price of feeder cattle for the first three quarters of 1973 and overestimated the price in the fall quarter of 1973. The projection for the winter quarter of 1974 was higher than the actual price. The spring quarter of 1973 had the largest deviation from the actual value with a difference of $8.00. The predicted value for the fall quarter of 1973 was $1.78 over the actual price, while the predicted value for the winter quarter of 1974 was $1.06 higher than the actual price.

Model I underestimated the quantity of feeder cattle for the first two quarters of 1973 by around 33400 and 91100 head, respectively, while overestimating the last two quarters of 1973 by only 1085 and 10200 head, respectively. The projection for the winter quarter of 1974 was greater

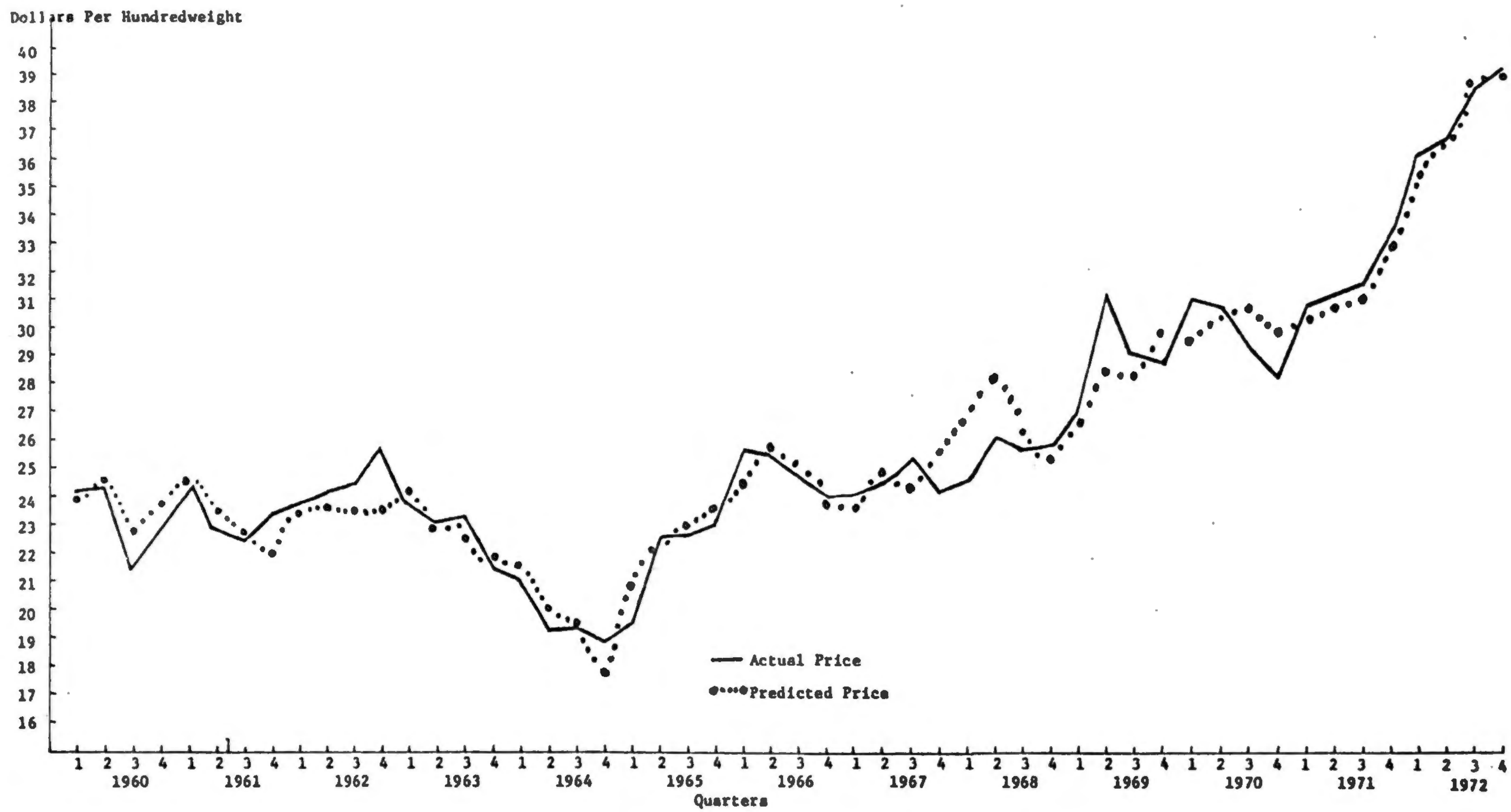

Figure 2. Actual and predicted price of feeder cattle in the United States, using Model I, 1960-72.

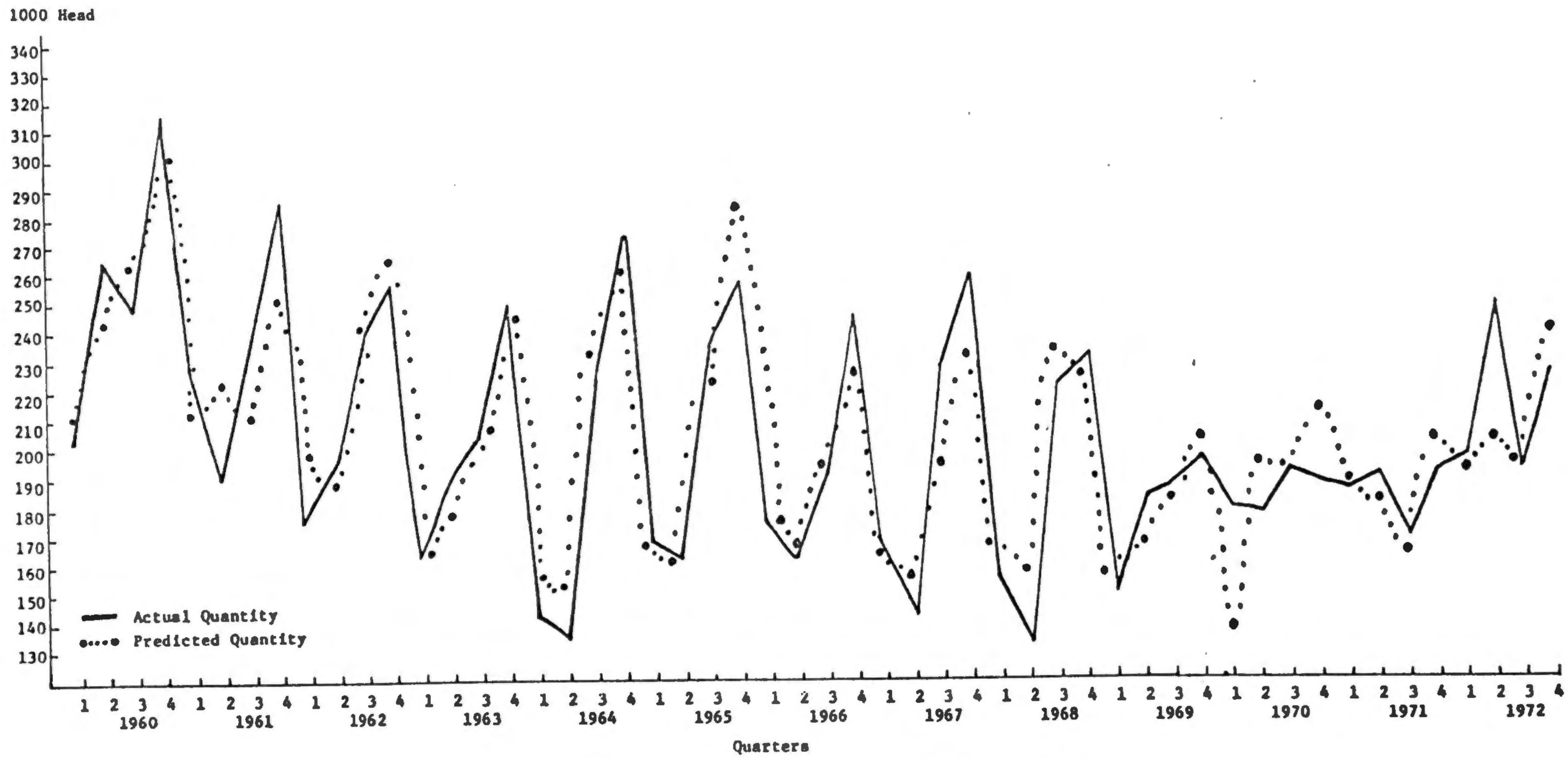

Figure 3. Actual and predicted quantity of feeder cattle in the United States, using Model I, 1960-72.

TABLE 10. ACTUAL VALUES, PREDICTED VALUES, AND DEVIATIONS OF THE QUARTERLY PRICE AND QUANTITY OF FEEDER CATTLE USING PREDICTIVE MODEL I; WINTER QUARTER 1973 THROUGH WINTER QUARTER 1974

Variable		Year and Quarter 1973 Winter	1973 Spring	1973 Summer	1973 Fall	1974 Winter
Price of Feeder Cattle ($/cwt.)	Actual	46.28	48.55	53.55	45.64	45.36
	Prediction	39.62	40.55	45.67	47.64	46.42
	Deviation	-6.66	-8.00	-7.88	1.78	1.06
Quantity of Feeder Cattle (head)	Actual	251967	261709	182499	197706	227616
	Prediction	218531	170599	183584	207906	283626
	Deviation	-33436	-91110	1085	10200	56010

than the actual quantity by around 56000 head.

Visual observation of the difference between the actual and predictive values is a subjective evaluation of the performance of a forecasting model. Therefore, two tests were used to more objectively evaluate the accuracy of these predictions.

The first test evaluated the predictions on the basis of direction of change in the endogenous variable.[13] A prediction was called "correct" if the estimated change from period "t-1" to period "t" was in the same direction as the actual change between the two periods. A prediction was "incorrect" if the estimated change from "t-1" to "t" was in a different direction than the actual change. A probability function can be used to evaluate the number of correct predictions obtained from the predictive model. The function used was similar to the expected results of a coin tossing experiment where the probability of a success is equal to the probability of a failure by chance alone. The probability of the occurrence of the number of "correct" (P) and "incorrect" (Q) predictions in the price and quantity of feeder cattle, due to chance alone, are given by the terms of the binomial expression $(P+Q)^5$, where P = 1/2 and Q = 1/2. The number of correct predictions for Model I and the probability of that number being due to chance alone are given in Table 11.

It was found that Model I predicted four out of five directions of change for the price of feeder cattle. There were three correct directions predicted for the quantity of feeder cattle. The probability of this number of correct predictions due to chance alone was .156 and

[13]For a detailed explanation of the test see Hee (1966).

TABLE 11. QUALITATIVE AND QUANTITATIVE TESTS OF THE PREDICTED VALUES OF THE PRICE AND QUANTITY OF FEEDER CATTLE IN THE UNITED STATES USING DIFFERENT FORECASTING MODELS, WINTER QUARTER 1973 THROUGH WINTER QUARTER 1974

Model[a]	Correct[b] Predictions of Price	Probability[c]	Correct[b] Predictions of Quantity	Probability	"U"[d] Value Price	"U"[d] Value Quantity
I_t	4	.156	3	.313	.064	.112
II_{t-1}	4	.156	4	.156	.087	.126
II_{t-2}	2	.313	3	.313	.076	.118
III_{t-1}	3	.313	4	.156	.078	.087
III_{t-2}	2	.313	5	.031	.081	.037

[a]Subscripts indicate the number of quarters that the independent variables which were measured in time period "t" were lagged in the predictive model.

[b]Correct prediction occurred when the predicted change from quarter t-1 to quarter t was in the same direction as the observed change.

[c]Probability of the same number of correct predictions occurring purely by chance alone, based on the binomial expansion $(P + Q)^5$, where $P = 1/2$ and $Q = 1/2$ and successive trials are independent.

[d]An index of dispersion designed to measure how closely the predicted values approximate the observed values.

.313 for price and quantity respectively.

The second test used to evaluate the predictive models was one that examined the accuracy of the magnitudes of the dependent variables. This test was an index of dispersion that measured how closely the predicted values approximated the actual values. This index of dispersion "U" was used to evaluate the models in this study with regard to magnitude.[14] The "U" values reported in this study were computed using the following formula:

$$U = \sqrt{\sum_{j=1}^{n} (P_j - A_j)^2 / N} \Bigg/ \sqrt{\sum_{j=1}^{n} P_j^2/N + \sum_{j=1}^{n} A_j^2 / N}$$

Where: P_j - are the predicted values for period $j=1 \cdot \cdot n$

A_j - are the actual values for period $j=1 \cdot \cdot n$

j - is prediction period with

N - being the total number of predictions.

If $U = 0$, then the predictions were perfect; if $U = 1$, then there was a negative proportionality between the predictions and the actual values. The "U" value for the price predictions of feeder cattle using Model I was .064, while the "U" coefficient for the quantity of feeder cattle was .112. This indicated that Model I was a better predictor of price than quantity.

It must be noted that 1973 was a rather atypical year. The price freeze, uncertainty of future prices and quantities, and high feed prices caused disruptions in the market that were not accounted for in the

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[14] The "U" coefficient was developed by Theil (1961) p. 32.

structural model. Therefore, Model I and subsequent models which were derived from the structural relationships may be less efficient in forecasting actual prices and quantities generated by these changes in the structure of the market.

Alternative Predictive Models

Often times the predictive properties of a structural model are not explored beyond what was done in the previous section; that is, predicting the respective dependent variables utilizing all independent variables in the structural model. This may have resulted in many models being shelved because they were deemed too complex or because of the difficulty in obtaining such large amounts of data.

In order for a forecasting model to be useful and practical for extension personnel and others in preparing production and marketing schedules; it must be small yet efficient, simple to use, and adaptable to the data available. This section will attempt to evaluate alternatives to Model I for forecasting feeder cattle price and quantity which satisfy these criteria.

Predictive Model II

One of the first objections or difficulties encountered in using Model I as a forecasting model was that many of the explanatory variables in the model were measured in the same time period as the dependent variable they were trying to predict. This is very impractical because if the values of the independent variables were known for that period, then the value of the dependent variable, a forecast variable, would also be known.

One possible solution to this problem was to use a lagged value for each independent variable that was measured in the same time period as the variable being predicted. In this study, the lag would most likely be one quarter so that the actual value and the lagged value would be as close together as possible.

Predictive Model II consisted of the same variables and estimated coefficients as Model I, however, the values of all independent variables that were measured in time period "t" were lagged one quarter. The predictions of the price and quantity of feeder cattle in the United States for the four quarters of 1973 and the first quarter of 1974 are presented in Table 12.

Using the lagged values of each independent variable that were measured in time period "t" resulted in predictions that were less accurate than the results using Model I. The estimates of the price of feeder cattle using Model II were \$8.34, \$9.71, and \$10.76 less than the actual feeder cattle prices for the first three quarters of 1973 respectively, Table 12. The fall quarter estimate of 1973 using Model II was \$6.00 higher than the actual price. The predicted price for the winter quarter of 1974 was \$2.63 higher than the actual price that quarter, Table 12.

Model II overestimated the quantity of feeder cattle marketed in all but the summer quarter of 1973, Table 12. The closest this model came to the actual quantity marketed was in the fall quarter of 1973 when it overestimated the quantity by only 6541 head. When compared to Model I, this model was closer to the actual quantity marketed only in the spring and fall of 1973.

TABLE 12. ACTUAL VALUES, PREDICTED VALUES, AND DEVIATIONS OF THE QUARTERLY PRICE AND QUANTITY OF FEEDER CATTLE IN THE UNITED STATES USING PREDICTIVE MODEL II WITH A ONE QUARTER LAG ON ALL INDEPENDENT VARIABLES MEASURED IN TIME PERIOD "T", WINTER QUARTER 1973 THROUGH WINTER QUARTER 1974

Variable		Year and Quarter 1973				1974
		Winter	Spring	Summer	Fall	Winter
Price of Feeder Cattle ($/cwt)	Actual	46.28	48.55	53.55	45.64	45.36
	Prediction	37.94	38.84	42.79	51.74	47.99
	Deviation	-8.34	-9.71	-10.76	6.10	2.63
Quantity of Feeder Cattle (head)	Actual	251967	261709	182499	197706	227616
	Prediction	335422	322794	163925	204247	323217
	Deviation	83455	61085	-18574	6541	95601

The number of correct predictions with regard to the direction of change and the associated probability along with the "U" value for the price and quantity of feeder cattle using Model II are presented in Table 11, page 73.

The "U" value for price indicated that Model I was a better predictor of price than Model II. However, the "U" value associated with quantity indicated that Model II was a relatively better predictor of quantity than Model I.

Model II correctly predicted four out of the five directions of change for the quantity of feeder cattle while Model I was able to predict three out of the five changes. The probability associated with getting this number of correct turns due to chance alone was .156 for Model II and .313 for Model I. Both models correctly predicted four out of the five directions of change in price with a probability of .156 of this being due to chance alone.

The results presented above indicate that using one quarter lagged values for all independent variables measured in the same time period as the dependent variable was a realistic alternative in developing a forecasting model from the structural model. However, the results also indicated that some loss of precision occurred as compared to the estimates derived from the reduced form model.

This procedure did not solve the problem of data availability that so often arises in forecasting. If a prediction of the fall quarter price of feeder cattle was needed during the summer quarter of a year, then using the above procedure one would need the data for summer quarter for all independent variables measured in time period "t". However, the data for most variables are usually not available until at least one month following the end of that quarter.

One possible solution to this problem was to use a two quarter lag for all independent variables measured in the same time period as the dependent variable. Then during summer quarter, if a prediction of the fall quarter price is needed, the spring quarter values of all independent variables measured in time period "t" would be the appropriate values to use in the forecasting model. The predictions of the price and quantity of feeder cattle for the four quarters of 1973 and the first quarter of 1974 using the coefficients of Model II and this technique are presented in Table 13.

Projections of the price and quantity of feeder cattle using Model II and a two quarter lag on all independent variables measured in time period "t" were slightly more efficient in predicting the magnitudes of price and quantity than Model II using a one quarter lag. The "U" coefficient was .087 for price using Model II and a one quarter lag as compared to a "U" coefficient of .076 for price using Model II and a two quarter lag. The "U" coefficient for quantity of feeder cattle was .126 using Model II with a one quarter lag and .118 using Model II with a two quarter lag on all independent variables measured in time period "t". Model II with a one quarter lag correctly predicted four out of the five directions of change for price and quantity of feeder cattle with a probability of .156 of this number being due to chance alone. Model II with a two quarter lag correctly predicted two out of the five directions of change for price and three out of the five directions for quantity with a probability of .313 of these numbers being due to chance.

TABLE 13. ACTUAL VALUES, PREDICTED VALUES, AND DEVIATIONS OF THE QUARTERLY PRICE AND QUANTITY OF FEEDER CATTLE IN THE UNITED STATES USING PREDICTIVE MODEL II WITH A TWO QUARTER LAG ON ALL INDEPENDENT VARIABLES MEASURED IN TIME PERIOD "T", WINTER QUARTER 1973 THROUGH WINTER QUARTER 1974

Variable		Year and Quarter 1973 Winter	Spring	Summer	Fall	1974 Winter
Price of Feeder Cattle ($/cwt)	Actual	46.28	48.55	53.55	45.64	45.36
	Prediction	42.08	47.28	41.50	48.86	54.57
	Deviation	-4.20	-1.27	-12.05	3.22	9.21
Quantity of Feeder Cattle (head)	Actual	251967	261709	182499	197706	227616
	Prediction	316532	314344	190401	184588	329615
	Deviation	64565	53635	7902	-13118	101999

Predictive Model III

The models discussed above used all the variables that were included in the first stage of the TSLS technique. This particular study involved 17 variables in the first stage which requires much data and time in developing quarterly forecasts. An attempt was made to alleviate this problem by developing a forecast model with fewer variables but one that would produce estimates similar to the previous models.

Model III consisted of five of the most statistically significant independent variables in the reduced form model along with the quarterly intercept shifters. The variables used to predict the price of feeder cattle in this model were: per capita consumption of pork, wage rate in the meat packing industry, price of feeder cattle lagged two quarters, cold storage holdings of beef, number of cattle on feed, and intercept shifters for quarters. The variables used to predict the quantity of feeder cattle were: price of feeder cattle lagged four quarters, wage rate in the meat packing industry, per capita disposable income, cow slaughter, number of cattle on feed, and intercept shifters for quarters. The estimated coefficients and standard errors of the variables included in Model III are presented in Table 21 of the Appendix.

Model III explained 95 percent of the variation in the price of feeder cattle and 76 percent of the variation in quantity. This compared to 96 percent of the variation in price and 84 percent of the variation in quantity explained by the complete model (Model I).

The predicted values of the price and quantity of feeder cattle using Model III with a one quarter lag are presented in Table 14. Model

TABLE 14. ACTUAL VALUES, PREDICTED VALUES, AND DEVIATIONS OF THE QUARTERLY PRICE AND QUANTITY OF FEEDER CATTLE IN THE UNITED STATES USING PREDICTIVE MODEL III WITH A ONE QUARTER LAG ON ALL INDEPENDENT VARIABLES MEASURED IN TIME PERIOD "T", WINTER QUARTER 1973 THROUGH WINTER QUARTER 1974

Variable		Year and Quarter 1973 Winter	1973 Spring	1973 Summer	1973 Fall	1974 Winter
Price of Feeder Cattle ($/cwt)	Actual	46.28	48.55	53.55	45.64	45.36
	Prediction	39.62	39.60	43.18	48.88	49.84
	Deviation	-6.66	-8.95	-10.37	3.24	4.48
Quantity of Feeder Cattle (head)	Actual	251967	261709	182499	197706	227616
	Prediction	243263	205040	180572	227464	289292
	Deviation	-8704	-56669	-1927	29758	61676

III underestimated the price of feeder cattle by $6.66, $8.95, and $10.37 in the first three quarters of 1973 respectively. The model overestimated the price in the fall quarter of 1973 and the winter quarter of 1974 by $324 and $4.48, respectively. This model underestimated the quantity of feeder cattle in the United States for the first three quarters of 1973 while overestimating the quantity in the fourth quarter of 1973 and the first quarter of 1974. The predicted quantities were less than the actual quantities by 8704, 5664, and 1927 head for the winter, wpring and summer quarters of 1973 respectively. The predicted values were 29758 head larger than the actual quantities for the fall quarter of 1973 and 61676 head larger than the actual quantity in the winter quarter of 1974.

Model III with a one quarter lag predicted three out of the five directions of change for the price of feeder cattle while correctly predicting four of the five directions of change for the quantity of feeder cattle. The probability of this number of correct predictions of the direction of change being due to chance alone was .313 for price and .156 for quantity. The correct number of predictions or the direction of change, the probability associated with these numbers, and the coefficient of dispersion of the predictions are given in Table 11, page 73.

The "U" coefficient for price in this model was .078 and the "U" coefficient for quantity was .087. This indicated that Model was able to predict the magnitude of the price of feeder cattle relatively better than the quantity of feeder cattle.

The technique of using a two quarter lag for all independent variables measured in time period "t" in order to alleviate the problem of data availability in forecasting was also applied to Model III. The projections for the price and quantity of feeder cattle in the United States for the four quarters of 1973 and the first quarter of 1974 using this procedure are presented in Table 15.

Model III with a two quarter lag was able to correctly predict two out of the five directions of change with respect to price with a probability of .313 of this number being due to chance alone. The model correctly predicted all five of the directions of change with respect to quantity. The probability of all five correct predictions of change in quantity being due to chance was .031. The number of correct predictions of the direction of change for the price and quantity, the probabilities associated with these numbers, and the "U" coefficients are presented in Table 11, page 73.

The "U" coefficient for the price projections using Model III with a two quarter lag was .081 while the "U" coefficient for quantity was .037. This indicated that the model was a better predictor of quantity than price. Model III using a two quarter lag was less efficient in predicting the price of feeder cattle than Model III using a one quarter lag. This was indicated by the "U" coefficient of price of .081 for Model III using a two quarter lag as compared to a "U" coefficient of .078 using Model III with a one quarter lag. A comparison of the "U" coefficients for quantity for Model III using the different lags indicated that Model III using a two quarter lag was more efficient in predicting the quantity of feeder cattle than Model III using a one quarter lag. Thus indicating

TABLE 15. ACTUAL VALUES, PREDICTED VALUES, AND DEVIATIONS OF THE QUARTERLY PRICE AND QUANTITY OF FEEDER CATTLE IN THE UNITED STATES USING PREDICTIVE MODEL III WITH A TWO QUARTER LAG ON ALL INDEPENDENT VARIABLES MEASURED IN TIME PERIOD "T", WINTER QUARTER 1973 THROUGH WINTER QUARTER 1974

Variable		Year and Quarter				
		1973				1974
		Winter	Spring	Summer	Fall	Winter
Price of Feeder Cattle ($/cwt)	Actual	46.28	48.55	53.55	45.64	45.36
	Prediction	41.40	39.40	42.17	45.85	51.63
	Deviation	-4.88	-9.15	-11.38	.21	6.27
Quantity of Feeder Cattle (head)	Actual	251967	261709	182499	197706	227616
	Prediction	222355	243601	190120	196803	235548
	Deviation	-29612	-18108	7621	-903	7932

that Model III with a two quarter lag was a good proxy for the larger models. However, it should be noted that Model III is a predictive model which was not based on the entire structure underlying the beef industry. Therefore, this model would be unreliable when large structural changes are occurring. Also this method of selecting the most significant variables to use in forecasting may imply that they are proxies for other relevant variables which happen to be correlated with them over this time period and are not assumed to be the true factors determining the price and quantity of feeder cattle. It is strongly suggested that Model II be used in making forecasts, however, if time does not permit the individual to obtain data on all 17 variables then Model III is an acceptable alternative.

An attempt was made to improve the predictive power of these models by re-estimating the coefficients using the lagged values for each independent variable measured in time period "t". However, this procedure actually resulted in forecasts that were less accurate than predictions using Model II and Model III.[15]

Comparison of the Predictive Models

Model I, which consisted of the reduced form equations of the TSLS technique, was used to predict the price and quantity of feeder cattle in the United States. The model performed relatively well in estimating the price and quantity of feeder cattle for the 52

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[15] An attempt was made to use the estimated coefficients of the second stage demand and supply functions of feeder cattle to project future prices and quantities. However, this attempt resulted in projections that were inferior in both magnitude and direction to the models discussed in this section.

observations used in estimating the coefficients of the model. This model was also fairly efficient in predicting the price and quantity of feeder cattle for the four quarters of 1973 and the first quarter of 1974 which were not used in estimating the structural models. However, the problems of having independent variables measured in the same time period as the dependent variable, data availability, and larger number of variables involved preclude this model from being a useful forecasting model.

Model II was developed as an alternative to Model I in an attempt to alleviate the problem of having independent variables measured in the same time period as the independent variables being predicted. The estimated coefficients of Model I were used along with a one quarter lag on all independent variables measured in time period "t" to predict the price and quantity of feeder cattle for the four quarters of 1973 and the first quarter of 1974. The predictions using this model were less efficient than the predictions using Model I, however the results indicated that using a lagged value was one solution to the problem of having independent variables measured in the same time period as the variable that is being forecasted with only a slight loss in predictive accuracy.

This procedure, however, did not solve the problem of data availability when making forecasts. The values of all independent variables measured in time period "t" were lagged two quarters and the estimated coefficients of Model II were used to predict the price and quantity of feeder cattle. This procedure insured the availability of data when making a forecast of the price or quantity of feeder cattle. These projections were reasonably close to the actual values indicating that this procedure could be used in developing a short run forecasting model from the structural relationships.

Another problem that often arises in using the reduced form of the structural model as a forecasting model is that there are usually a large number of variables included in the reduced form equations. This requires a large amount of data and time in making forecasts. An attempt was made to alleviate this problem by developing a predictive model with a small number of variables but one that could forecast prices and quantities of feeder cattle as efficiently as the larger models. Model III, which included the five most significant variables from the reduced form equations along with intercept shifters for quarters, was developed in an attempt to solve this problem.

The coefficients of Model III along with the values of all independent variables measured in time period "t" lagged one and two quarters were used to predict the price and quantity of feeder cattle. The results indicated that this procedure could be used to solve the problem of large numbers of variables, variables measured in the same time period as the dependent variable, and data availability. Therefore, it could be concluded that Model III using a two quarter lag might be considered as a possible alternative predictive model to Model I or Model II which would meet the criteria of being easy to use, have data available for making forecasts, and produce fairly efficient estimates of price and quantity. However, this model does not necessarily include the underlying structure which determined the true factors influencing feeder cattle price and quantity. It is recommended whenever possible that Model II with a two quarter lag be used in making forecasts.

Forecasting State Level Prices of Feeder Cattle Using the National Model

The forecasts of the prices and quantities of feeder cattle in the previous sections were for the United States. This may be the estimate that is relevant for many individuals, however, information may be needed regarding the price of feeder cattle at the state level.

An attempt was made to use the United States forecasts from the previous section, along with relevant data on the price of feeder cattle in Tennessee to develop a forecasting procedure for the Tennessee price of feeder cattle.

Theoretically, the difference between the national price of feeder cattle and the Tennessee price should be the cost of transportation in shipping these calves from one area to another (Goodwin, 1970). Therefore, the difference between the U.S. price and the Tennessee price of feeder cattle should remain relatively constant from one period to another.

Since there is no one price in Tennessee that could be called representative of the feeder cattle price, two different price series were analyzed. The first series used was the average price per hundredweight of choice 300-550 pound feeder steers sold in auction sales in Tennessee.[16] The second price series for which forecasts were made was the price per hundredweight of 300-500 pound choice feeder steers sold in organized feeder cattle sales in Tennessee.[17] These two series were

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[16]The price of choice steers sold through auction sales in Tennessee as reported by U.S. Agricultural Marketing Service.

[17]The price of choice steers sold through organized feeder cattle as reported by the University of Tennessee Extension Service.

used since organized feeder cattle sales and auction markets represent major outlets for feeder cattle in the state. Also, data for these series are available.

The first step in developing the forecast procedure for Tennessee prices of feeder cattle was to regress the Tennessee price of feeder cattle on the U.S. price of feeder cattle. The result of this regression was a coefficient that indicated the amount that Tennessee price changed for every one dollar change in the U.S. price. Since this coefficient expressed the change in dollars, it was decided to use the log value of the actual data so that the coefficient of the U.S. price would be in percentage terms. The estimated coefficient represents the percentage change in Tennessee price associated with a one percent change in the U.S. price.

The regression of the price of choice 300-500 pound feeder steers sold in auction sales in Tennessee on the U.S. price of feeder steers resulted in the following estimated equations:[18]

$$Y = -.35346 + 1.2876\ X$$

where: Y was the price of feeder cattle sold through auction sales in Tennessee in log form.

X was the average price of feeder steers all weights and grades sold out of first hands, seven markets in the United States.

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[18] The results of this regression indicated that Tennessee price of feeder cattle was higher than the U.S. price. However, it should be noted that the Tennessee price used in this study was the price for a specific weight of choice feeder steers whereas the U.S. price was the average price for all weights and grades of feeder steers.

This equation was used to predict the price of feeder cattle sold through auction sales in Tennessee. Since the actual U.S. price required to predict the Tennessee price of feeder cattle would not be available at the time the state prediction is made, the price of feeder cattle in the United States as estimated by Model II with a two quarter lag was used in making the predictions. The predicted values of the price of feeder cattle sold through auction sales in Tennessee are presented in Table 16.

The same procedure was applied to the price of 300-500 pound choice steers sold through organized feeder cattle sales in Tennessee. These sales are held only in the spring and fall quarters of each year. The estimated regression equation for these sales was as follows:

$$Y = -.1536 + 1.156\ X$$

where: Y was the price of feeder cattle sold through organized feeder cattle sales in Tennessee in log form.

X was the average price of feeder steers all weights and grades sold out of first hands, seven markets combined in the United States.

Again the price of feeder cattle in the United States as estimated by predictive Model II with a two quarter lag was used as the relevant price since the actual price would not be available at the time the prediction is being made. The predicted values of the price of feeder cattle sold through organized sales in Tennessee are presented in Table 16.

TABLE 16. ACTUAL VALUES, PREDICTED VALUES, AND DEVIATIONS OF THE PRICE OF FEEDER CATTLE SOLD THROUGH AUCTION SALES AND ORGANIZED FEEDER CATTLE SALES IN TENNESSEE, WINTER QUARTER 1973 THROUGH WINTER QUARTER 1974.

Variable		Year and Quarter 1973 Winter	Spring	Summer	Fall	1974 Winter
Price of Feeder Cattle Sold Through Auctions in Tennessee ($/cwt.)	Actual	59.43	61.88	65.53	53.97	51.76
	Prediction	54.65	63.51	53.69	66.28	76.40
	Deviation	- 4.79	1.63	-11.84	12.31	24.64
Price of Feeder Cattle Sold Through Organized Feeder Cattle Sales in Tennessee ($/cwt.) [a]	Actual	-	61.60	-	60.17	-
	Prediction	-	60.59	-	62.92	-
	Deviation	-	1.01	-	2.75	-

[a]Organized feeder cattle sales are held only in the spring and fall of each year.

The predicted values of the price of feeder cattle sold through auction sales in Tennessee were lower than the actual prices for the winter and summer quarters of 1973. The predicted values were higher than the actual values for the spring and fall quarters of 1973 and the winter quarter of 1974. The predicted price was $4.79 and $11.84 less than the actual price for the winter and summer quarters of 1973 respectively. The predicted price was $1.63, $12.31, and $24.64 higher than the actual price during spring and fall of 1973 and winter of 1974 respectively.

The predicted value of the price of feeder cattle sold through organized feeder cattle sales in Tennessee was $1.01 less than the actual price in the spring of 1973 and $2.75 higher than the actual price in the fall quarter of 1973.

The projections for Tennessee prices were not as accurate as the projections for the U.S. price. This could be due to several factors not evaluated in this analysis. The major factor being that the relationship between the U.S. price and Tennessee price is more than transportation costs. It could depend on such factors as time of the year, weather conditions, and differences in price expectations of Tennessee farmers versus all U.S. farmers.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study attempted to develop an econometric model to describe the feeder cattle sector of the beef cattle industry in the United States. The structural relationships specified by this model were used to develop several forecasting models for the price and quantity of feeder cattle. A brief summary of the statistical and economic findings and the conclusions and implications based upon these results are presented in this chapter.

I. SUMMARY

Structural Model

The model hypothesized to describe the feeder cattle industry consisted of eight behavioral equations and two market clearing equations. The eight behavioral equations were: (1) the quarterly demand for feeder cattle, (2) the quarterly supply of feeder cattle, (3) the quarterly packer level demand for slaughter cattle, (4) the farm level supply of slaughter cattle, (5) the farm to retail marketing margin for beef, (6) the retail demand for beef, (7) the retail demand for pork, and (8) the retail demand for chicken. This set of equations were overidentified and were estimated using the two-stage least-squares technique with the variables measured in actual values. Quarterly intercept shifters were included in all equations except the marketing margin equation.

The farm level demand for feeder cattle and slaughter cattle was considered as the demand for an input since feeder cattle are a major input for the feedlot operator while slaughter cattle are a major input into the packing industry. The two farm level demand equations were normalized on their particular market price. The current price of feeder cattle was found to be most influenced by the present quantity of feeder cattle and the current price of slaughter cattle. The estimated demand relationship for feeder cattle was found to be highest in the winter and fall quarters which was attributed to the seasonal pattern of the demand for feeder cattle. The retail price of beef and the number of cows slaughtered were found to have a significantly positive influence on the current price of slaughter cattle. The quantity of slaughter cattle had a negative influence on the price of slaughter cattle; however, the coefficient was not significant.

The quantity of feeder cattle supplied was hypothesized to be a function of the current price of feeder cattle, the calf crop lagged two quarters, the lagged price of feeder cattle, and a time variable. The current price of feeder cattle, time, and quarterly intercept shifters were found to have a significant impact on the supply of feeder cattle. The current price of feeder cattle had a positive influence on quantity while time had a negative influence.

The supply of slaughter cattle was found to be significantly influenced by the current price of slaughter cattle, the lagged price of feeder cattle, and time. The current price of slaughter cattle had a negative sign which was contrary to economic theory. However, it was believed that expected prices influenced the quantity supplied more than the present price and thus the negative quantity-price relationship. The lagged price of feeder cattle and time had a negative influence on the quantity of slaughter cattle.

A marketing margin was used to connect the price of beef cattle at the farm level to the price of beef at the retail level. The farm to retail marketing margin for beef was found to be significantly influenced by the current price and quantity of slaughter cattle, the wage rate in the meat packing industry, and time. The marketing margin was found to have declined slightly over the period covered in this study.

Beef, pork, and chicken were assumed to be competitors for the consumers' meat dollars at the retail level. The current price of pork and chicken was assumed to influence the quantity of beef consumed. However, the current price of beef also affects the consumption of pork and chicken. Since the direction of causality was assumed to be both ways between any combination of the three meats, a demand function for pork and chicken was also developed. The production of pork and chicken was assumed to be predetermined.

The retail price of beef was found to have a significantly negative effect on the per capita quantity of beef demanded while the retail price of pork and chicken and income were found to have a significantly positive effect. The quantity of beef demanded was found to be highest during the summer quarter and lowest during the winter quarter.

Since the quantity of pork and chicken was assumed to be predetermined during any one quarter, the demand function for these two meats was normalized on their respective prices. The quantity of pork, the quantities of beef and chicken, and income had a significant influence on the retail price of pork. All variables conformed to a priori expected signs except the quantity of chicken which had a positive sign. This indicated that chicken was a complement to pork. However, in the demand function for chicken, pork was found to be a substitute for chicken. It seems unlikely that consumers would consider the two meats complements in one case and substitutes in another case. One possible explanation was that income and the quantity of chicken were highly correlated. The demand function for pork was found to be the highest in the fall and winter and lowest in the spring and summer.

The quantity of pork and the quantity of beef were found to have a significantly negative influence on the price of chicken. Income was found to have a significantly positive influence on the retail price of chicken. The per capita consumption of chicken was found to have a negative influence on the price of chicken; however, the estimated coefficient was smaller than its standard error. The demand relationship for chicken was found to be highest in the summer and lowest in the fall.

Elasticities and Flexibilities

Relevant elasticities and flexibilities were computed from the estimated relationships of the structural model. These estimates were computed using the estimated coefficients in the second stage of the TSLS technique and the means of all 52 observations for the particular variables.

The price flexibility of demand for feeder cattle was found to be -0.15 for feeder cattle indicating that for every one percent increase in quantity of feeder cattle the price decreased .15 percent. The price flexibility of demand for slaughter cattle was -.02. This compared to a price flexibility of -1.626 obtained by Prato and Havlicek (1965) in their analysis of the demand for slaughter cattle at the farm level. These results indicated that the price of feeder cattle fluctuated more with a one percent change in quantity than did the price of slaughter cattle.[19]

The price elasticity of supply for feeder cattle was 0.28 while the price elasticity of supply for slaughter cattle was -0.88. Since the price-quantity relationship of slaughter cattle was negative, the price elasticity of supply for slaughter cattle indicated that for every one percent increase in the price of slaughter cattle, quantity supplied decreased 0.88 percent.

A price reaction coefficient was computed between the price of feeder cattle and the price of slaughter cattle. The estimated coefficient was 1.03 indicating that the price of feeder cattle increased 1.03 percent for every one percent increase in the price of slaughter cattle. The price reaction coefficient between the price of slaughter cattle and the retail price of beef was 1.07. This indicated that during periods of rising prices of slaughter cattle and retail beef, meat packers tend to bid up the price of their major input, more than feedlot operators.

The price elasticity of demand for retail beef was found to be -0.72. This compared to an elasticity of demand of -.85 obtained by Maki (1959) in a study of beef cattle and hog prices. Elam (1973) estimated a price elasticity of demand for beef of -.50 in his study of

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[19] Estimates of the price flexibility of demand for feeder cattle are not readily available since little econometric work has been done in the feeder cattle sector.

the beef-pork sector. The cross price elasticity of demand for beef with respect to pork and chicken was found to be .06 and .12, respectively. This compared to estimates of the cross elasticities of pork and chicken of .117 and .062 obtained by Elam (1973). The income elasticity of demand for beef was 0.79 in this study as compared to 0.56 in the study conducted by Elam (1973). Myers and Havlicek (1970) found an income elasticity for beef of 1.104.

The price flexibility of demand for pork and chicken was -1.16 and -0.14, respectively. The price flexibility for chicken in this study compared to estimates of 0.26 obtained by Elam (1973) and -.70 obtained by Myers and Havlicek (1970). The estimates obtained in this study indicated that the retail prices of pork fluctuate more than retail prices of chicken given a one percent change in the consumption of each meat. The income flexibility for pork and chicken was 0.74 and 0.40, respectively.

Short-Run Forecasting

The estimated relationships of the reduced form of equations and the structural model itself were used in formulating several predictive models for the price and quantity of feeder cattle. These models varied in complexity and structure. The predictive values generated by the various models were compared to the actual values of the price and quantity of feeder cattle for the four quarters of 1973 and the first quarter of 1974, which were the five quarters immediately following the time period used to estimate the coefficients included in each model. The predicted values were subjected to two tests in order to judge their ability to forecast. The first test was concerned with predicting the direction of change from one quarter to the next. The second test was concerned with the ability of the models to predict the magnitude of the price and quantity of feeder cattle.

Predictive Model I was developed using all the variables included in the first stage of the TSLS technique. This model was used to predict the values of the price and quantity of feeder cattle for the 52 quarters used in estimating the coefficients of the model. The model was able to predict 38 of the 52 directions of change for price and 42 out of 52 for quantity. The ability of Model I to forecast values of the price and quantity of feeder cattle for quarters not included in the sample was also tested. The model was used to predict the price and quantity of feeder cattle for the four quarters of 1973 and the first quarter of 1974. The model underestimated the price of feeder cattle for the first three quarters of 1973 and overestimated the fourth quarter of 1973 and the first quarter of 1974. The deviation of the predicted price from the actual price was as much as $8.00 per hundredweight, which occurred in the spring quarter of 1973. The model underestimated the quantity of feeder cattle the first two quarters of 1973 and overestimated the fourth quarter of 1973 and the first quarter of 1974.

Several difficulties were encountered in using Model I as a forecasting model. The first difficulty was that several of the independent variables included in the model were measured in the same time period as the variable that was being predicted. Model II was developed in an attempt to alleviate this problem. Model II used the same variables as Model I: however, a lagged value of each variable measured in time period "t" was used in making the predictions. Model II was able to predict the same number of directions of change of price as Model I. Model II correctly predicted four out of the five directions of change for quantity while Model I predicted three out of the five for quantity. The predicted magnitudes of price and quantity using Model II with a one quarter lag deviated more from the actual values as indicated by the "U" coefficients. The "U" coefficient for price in Model I was .064 as compared to the "U" coefficient for price in Model II of .087. The "U" coefficient for quantity in Model I was .112 as compared to .126 for Model II. The largest deviation between the predicted price and actual price was $10.76 which occurred in the summer quarter of 1973. The largest deviation in quantity was 95,601 head in the winter quarter of 1974.

The procedure of using a one quarter lag on all independent variables measured in time period "t" did not solve the problem of having data available to make forecasts for future quarter prices and quantities. Therefore, a two quarter lag was used on all independent variables included in the model that were measured in time period "t". This assured the availability of data for making forecasts at least one quarter into the future.

Model II with a two quarter lag on all independent variables measured in time period "t" was used to predict the price and quantity of feeder cattle for the four quarters of 1973 and the first quarter of 1974. The results indicated that this model was slightly more efficient in predicting the magnitudes of the price and quantity of feeder cattle than Model II using a one quarter lag. This was evidenced by the fact that the "U" coefficient for price using Model II and one quarter lag was .087 as compared to .076 for Model II using a two quarter lag. The "U" coefficient for quantity was .126 for Model II using a one quarter lag and .118 for Model II using a two quarter lag. Model II with a one quarter lag was able to predict the directions of change for the price and quantity of feeder cattle more accurately than Model II with a two quarter lag. Model II with a one quarter lag correctly predicted four out of five directions of change for both price and quantity with a probability of .156 of this number being due to chance alone. Model II with a two quarter lag predicted two out of the five directions of change for price and three out of five directions for quantity. The probability of this number being due to chance alone was .313 for both price and quantity.

Predictive Model III was developed to alleviate the difficulty of a large number of variables in a predictive model which requires much data and time when making forecasts. This model consisted of the five most statistically significant variables in the reduced form equation along with the quarterly intercept shifters. Model III with a one quarter lag on all independent variables measured in time period "t" correctly predicted three out of the five directions of change for price and four out of the five directions for quantity. The probability of these numbers being due to chance alone was .313 for price and .156 for quantity. The "U" coefficient for price in this model was .078 while the "U" coefficient for quantity was .087. The largest deviation between the actual price and the predicted price was $10.37 per hundredweight which occurred in summer quarter of 1973. The largest deviation in quantity was 61,676 head ih the winter quarter of 1974.

A two quarter lag on all independent variables measured in time period "t" was also used with the coefficients of Model III in order to alleviate the problem of not having data available for forecasting. This procedure resulted in price predictions that were correct with respect to the direction of change two out of the five quarters tested. This model correctly predicted all five directions of change for quantity. The "U" coefficient for price was .081 and .037 for quantity indicating that Model III using a two quarter lag was a better predictor of quantity than price. However, it should be noted that Model III was not formulated using the underlying structure of the beef cattle industry; therefore, it is suggested that Model III using a two quarter lag be used in making forecasts of price and quantity of feeder cattle.

Predictive Models I-III were all designed to predict the price and quantity of feeder cattle in the United States. Information regarding the price of feeder cattle may also be required at the state level. An attempt was made to develop a procedure that could be used to estimate the price of feeder cattle in Tennessee using the information obtained from the previous models. This was accomplished by regressing the Tennessee price of feeder cattle on the U.S. price of feeder cattle, where both variables were in log form. The estimated equation was used to predict the price of feeder cattle in Tennessee. The estimated coefficient of the U.S. price of feeder cattle indicated the percentage change in the Tennessee price of feeder cattle associated with a 1 percent change in U.S. price of feeder cattle. Since the actual price of feeder cattle in the United States is not known for the quarter that a forecast is required, the predicted value of the U.S. price as estimated by Model II using a two quarter lag was substituted for the actual value in that quarter.

This procedure was applied to the price of 300-550 pound choice feeder steers sold through auction sales in Tennessee and to the price of 300-500 pound choice feeder steers sold through organized feeder cattle sales. These series were used since auction sales and organized feeder cattle sales represent the two major outlets for feeder cattle in Tennessee.

This procedure yielded predictions of the price of feeder cattle sold through auctions in Tennessee that were relatively close to the actual prices for the four quarters of 1973 and the first quarter of 1974. The largest deviation was $24.64 per hundredweight which occurred in the winter quarter of 1974.

The projections for the price of feeder cattle sold through organized feeder cattle sales deviated from the actual prices by $1.01 and $2.75 in the spring and fall quarters of 1973, respectively.

Predictions

Predictions of the price of feeder cattle in the United States and Tennessee were made for the spring and summer quarters of 1974. Model II with a two quarter lag was used to predict the price in the United States. These estimates were used to predict the Tennessee price of feeder cattle sold through auction sales and organized feeder cattle sales using the procedure discussed in Chapter IV.

Model II with a two quarter lag on all independent variables measured in time period "t" predicted the price in the United States to be $48.00 in the spring quarter of 1974 and $46.88 for the summer quarter of 1974. The projections for the price of feeder cattle sold through auction sales in Tennessee were $64.73 for spring quarter and $61.39 for summer quarter of 1974. The spring quarter price of feeder cattle sold through organized feeder cattle sales in Tennessee was projected to be $61.64.

These projections seem high when compared to the current feeder cattle prices. However, the models did yield projections that were below the fall quarter price of 1973 and the winter quarter price of 1974. Projections for these two quarters as reported by Agricultural Outlook and Western Livestock Roundup were for lower prices. The models were able to predict the downswing in price but seemed to miss the magnitude.

II. CONCLUSIONS

Several general conclusions can be drawn from the results of the analysis of the quarterly demand supply relationships for feeder cattle discussed in the previous chapters.

First, the feeder cattle sector of the beef industry can be described with a set of simultaneous equations. The current quantity in the demand equation for feeder cattle had a significant effect on the price of feeder cattle. Also, the price of feeder cattle in the supply equation had a significant effect on the quantity supplied.

The current effect of price as a coordinator between the various levels of the marketing channel for beef seemed to be significant since the retail price of beef had a significant influence on the price paid for slaughter cattle. Also the price of slaughter cattle had a significant influence on the price of feeder cattle.

These results would indicate that the price of feeder cattle would tend to fluctuate more than the price of slaughter cattle given a percentage change in the quantities of both since the price flexibility of demand was -0.15 for feeder cattle and -0.02 for slaughter cattle.

A predictive model consisting of all the variables included in the first stage of the TSLS technique was able to track past sample data rather well. However, several problems preclude this model from actually being used as a forecast model.

A model using all the variables in the first stage along with the lagged values of all variables measured in time period "t" is a good alternative forecasting model to use to avoid the problem of having some independent variables measured in the same time period as the variable being predicted.

To avoid the problem of having to keep a data series on all variables included in the structural model for forecasting purposes, an alternative that performs rather efficiently is to use only the five most statistically significant variables in the first stage as a forecasting model. However, it is suggested that this model only be used when limitations on time and data availability preclude the use of Model II since Model III does not include the complete structure underlying the beef cattle economy.

Re-estimating the coefficients when lagged values are used when a variable is measured in time period "t" actually reduces the accuracy of the forecasts.

The prices of feeder cattle in the United States as estimated by these models can be used to arrive at appropriate state level estimates of the price of feeder cattle.

III. SUGGESTIONS FOR FUTURE RESEARCH

Several areas of further analysis are suggested by the results of this study. This study focused on the demand and supply of feeder cattle in the United States. Studies which focus on regional demand and supply of feeder cattle and how they relate to the national model are also needed.

The possibility of expanding the predictive nature of this model by adding the additional equations necessary to make this a simultaneous recursive system is a possibility for future research.

The inclusion of some aspects of the futures market prices in the model might help account for some of the variations in price within the beef cattle sector.

An additional suggestion for further research would be to develop alternative means of getting efficient state level forecasts from the predictions generated by the national models.

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APPENDIX

TABLE 17. ARITHMETIC MEANS AND STANDARD DEVIATIONS OF THE VARIABLES INCLUDED IN THE ECONOMIC MODEL, 1960-1972

Variable	Units	Arithmetic Mean	Standard Deviation
$P^*_{FC(t)}$	$/Hundredweight	26.126	4.795
$Q^*_{FC(t)}$	Head	203270.00	40334.000
$P^*_{SC(t)}$	$/Hundredweight	26.378	3.873
$P_{FC(t-4)}$	$/Hundredweight	25.267	3.445
$Q^*_{SC(t)}$	Head	531350.00	168730.00
$P^*_{B(t)}$	¢/Pound	87.681	11.434
$P^*_{P(t)}$	¢/Pound	66.602	9.282
$Q^*_{B(t)}$	Pounds/Person	25.271	2.754
$Q_{P(t)}$	Pounds/Person	15.708	1.330
$Q_{CH(t)}$	Pounds/Person	7.806	1.341
$P_{C(t)}$	$/Bushel	1.237	.122
$P^*_{CH(t)}$	$/Pound	40.246	1.862
$WR_{(t)}$	$/Hour	3.313	.573
$I_{(t)}$	Percent	4.674	1.516
$P_{C(t-2)}$	$/Bushel	1.229	.123
$P_{FC(t-2)}$	$/Hundredweight	25.603	4.045
T	Quarters	26.500	15.008
$Y_{(t)}$	$/Person	674.120	152.730
$CI_{(t)}$	1000 Pounds	245340.000	63300.000
$CS_{(t)}$	1000 Head	1321.000	246.610

TABLE 17 (continued)

Variable	Units	Arithmetic Mean	Standard Deviation
M_1		1321.000	246.610
M_2		.250	.433
M_3		.250	.433
$CC_{(t-2)}$	1000 Head	6010.200	1095.200
$HOF_{(t)}$	1000 Head	9098.300	2126.400

TABLE 18. CORRELATION MATRIX OF THE INDEPENDENT VARIABLES IN THE ECONOMIC MODEL

	INDEPENDENT VARIABLES																
	P_{FC} (t-4)	Q_P (t)	Q_{CH} (t)	P_C (t)	WR (t)	I (t)	P_C (t-2)	P_{FC} (t-2)	T	Y (t)	CI (t)	CS (t)	M_1	M_2	M_3	CC (t-2)	HOF (t)
$P_{FC(t-4)}$	1.00	.64	-.57	-.37	.78	.31	.25	.87	.60	.71	.52	-.14	-.01	-.01	-.05	.61	.61
$Q_{P(t)}$		1.00	.33	.19	.64	.25	.45	.58	.57	.60	.61	.15	.07	-.30	.43	.59	.46
$Q_{CH(t)}$			1.00	.55	.86	.67	.35	.69	.91	.90	.67	.42	-.29	.25	-.14	.88	.78
$P_{C(t)}$				1.00	.47	.29	.49	.33	.51	.50	.47	.23	-.27	.12	-.23	.49	.50
$WR_{(t)}$					1.00	.58	.43	.87	.95	.99	.77	.36	-.05	.01	.07	.95	.86
$I_{(t)}$						1.00	.16	.44	.69	.65	.65	.50	-.05	.05	.02	.63	.62
$P_{C(t-2)}$							1.00	.28	.48	.47	.60	.44	.12	.01	.17	.53	.36
$P_{FC(t-2)}$								1.00	.74	.82	.58	.07	-.07	.05	.11	.75	.68
T									1.00	.99	.83	.52	-.06	.02	.06	.99	.89
$Y_{(t)}$										1.00	.80	.45	-.06	.02	.05	.98	.88
$CI_{(t)}$											1.00	.47	.08	-.14	.22	.84	.75
$CS_{(t)}$												1.00	-.02	.11	.40	.56	.26
M_1													1.00	-.33	-.33	-.07	.28
M_2														1.00	-.33	.06	-.17
M_3															1.00	.11	-.24
$CC_{(t-2)}$																1.00	.85
$HOF_{(t)}$																	1.00

TABLE 19. ACTUAL VALUES, PREDICTED VALUES, AND DEVIATIONS OF THE PRICE AND QUANTITY OF FEEDER CATTLE IN THE UNITED STATES USING PREDICTIVE MODEL I, 1960-1972

Year and Quarter		Actual Price	Predicted Price	Deviation	Actual Quantity	Predicted Quantity	Deviation
		Dollars			Head		
1960	1	24.17	24.04	.13	202200	212204	-10004
	2	24.28	24.38	- .10	262822	242321	20501
	3	21.55	23.00	-1.45	249043	265421	-16378
	4	22.98	23.67	- .69	316138	301630	14508
1961	1	24.29	24.43	- .14	222931	217023	5908
	2	22.96	23.56	- .60	190668	221562	-30896
	3	22.52	22.67	- .14	225856	211786	14070
	4	23.36	22.12	1.24	284212	251013	33199
1962	1	23.76	23.41	.35	176844	198976	-22132
	2	24.26	23.63	.63	185540	189340	6210
	3	24.65	23.47	1.18	238112	239612	- 1450
	4	25.68	23.42	2.26	256088	265210	- 9120
1963	1	23.88	24.03	- .15	163002	163942	- 940
	2	23.10	23.03	.07	188592	170685	17907
	3	23.16	22.63	.53	202219	207063	- 4844
	4	21.47	21.79	- .32	249552	245271	4281
1964	1	21.21	21.63	- .42	145712	155773	-10061
	2	19.19	20.13	- .94	135935	153081	-17146
	3	19.19	19.29	- .10	225133	230515	- 5382
	4	18.86	17.93	.93	272865	260222	12642
1965	1	19.46	20.87	-1.41	169236	169113	123
	2	22.55	22.16	.39	162033	163554	- 1521
	3	22.62	22.77	- .15	233358	228890	4468
	4	23.02	23.62	- .60	256574	281873	-25299
1966	1	25.68	24.48	1.20	176506	174292	2214
	2	25.22	25.77	- .55	162028	163528	- 1500
	3	24.87	25.14	- .27	188778	192656	- 3878
	4	24.07	23.92	.15	245133	227553	17580
1967	1	24.10	23.65	.45	172223	164083	8140
	2	24.56	24.74	- .18	140385	154858	-14473
	3	25.44	24.55	.89	222445	204895	17550
	4	24.27	25.70	-1.43	258877	231174	27703
1968	1	24.75	26.84	-2.09	154115	167283	-13168
	2	26.13	28.19	-2.06	136079	158861	-22782
	3	25.93	26.28	- .35	221670	233408	-11738
	4	25.94	25.57	.37	230151	227773	2378
1969	1	27.01	26.86	.15	152452	155686	- 3234
	2	31.33	28.50	2.83	182194	166664	15530
	3	29.23	28.40	.83	186092	180439	-17640
	4	28.96	29.96	-1.00	195965	213605	-17640

TABLE 19 (continued)

Year and Quarter		Actual Price	Predicted Price	Deviation	Actual Quantity	Predicted Quantity	Deviation
		Dollars			Head		
1970	1	31.13	29.87	1.26	178374	138622	39752
	2	30.59	30.95	.36	177824	194532	-16708
	3	29.57	30.99	-1.42	190978	191968	- 990
	4	28.68	30.13	-1.45	186909	214731	-27822
1971	1	30.91	30.84	.07	185294	185719	- 425
	2	31.28	30.98	.30	188602	181228	7374
	3	31.76	31.14	.62	167583	164202	3381
	4	33.60	33.14	.46	188917	204430	-15513
1972	1	36.27	35.68	.59	194973	191155	3818
	2	36.84	36.98	- .14	244683	207189	37494
	3	38.55	38.72	- .17	193383	193803	- 420
	4	39.33	39.23	.10	222813	239715	-16902

TABLE 20. ESTIMATED COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE VARIABLES INCLUDED IN PREDICTIVE MODELS I AND II

Independent Variable	Price		Quantity	
	Coefficient	Standard Error	Coefficient	Standard Error
Constant	-3.813	-	415000	-
$P_{FC(t)}$	.330	.1774	11500	2984
$Q_{P(t)}$	-1.049	.3146	-10070	5293
$Q_{CH(t)}$	3.325	.8760	3063	14740
$P_{C(t)}$	-2.790	1.9520	-37670	32840
$WR_{(t)}$	2.671	4.6710	125300	78590
$I_{(t)}$	.396	.3045	-5705	5123
$P_{C(t-2)}$	3.869	2.6830	-52330	45140
$P_{FC(t-2)}$	.145	.1972	2653	3319
T	-.307	.2980	8424	5014
$Y_{(t)}$	.021	.0338	-958.9	568.7
$CI_{(t)}$	.00004	.000009	-.08	.15
$CS_{(t)}$	-.00381	.0021	138	36.02
M_1	.843	1.194	35630	20090
M_2	-.557	1.601	-40770	26930
M_3	3.014	2.355	19470	37930
$CC_{(t-2)}$	.004	.002	-7.396	39.89
$HOF_{(t)}$	.0006	.0010	-44.380	16.46

TABLE 21. ESTIMATED COEFFICIENTS AND RESPECTIVE STANDARD ERRORS OF THE VARIABLES INCLUDED IN PREDICTIVE MODEL III

Independent Variable	Dependent Variable			
	Price		Quantity	
	Coefficient	Standard Error	Coefficient	Standard Error
Intercept	4.491	-	-3065	-
$Q_{P(t)}$	-.646	.221	-	-
$WR_{(t)}$	7.276	1.480	129900	52670
$P_{FC(t-2)}$	.514	.095	-	-
$CI_{(t)}$	-.000025	.000006	-	-
$HOF_{(t)}$	.000069	.000366	-20.83	8.822
$P_{FC(t-4)}$	-	-	5372	2186
$Y_{(t)}$	-	-	-459.10	260.100
$CS_{(t)}$	-	-	106.50	26.91
M_1	.632	.562	2721.00	11050.00
M_2	-1.051	.664	-10730.00	13520.00
M_3	.449	.825	1311.00	16360.00

VITA

Joe T. Davis was born in Martin, Tennessee on January 22, 1946. He graduated from Martin High School in 1964. The following September he entered the University of Tennessee at Martin and in June, 1968 received the Bachelor of Science degree in General Agriculture. In September 1968 he accepted a National Defense Educational Act Fellowship at the University of Tennessee, Knoxville and began working towards a Master's Degree. In February of 1969 he entered the United States Army for two years active duty. He was discharged from the Army in December of 1970 and returned to the University of Tennessee to complete graduate work. He received the M.S. degree in December of 1972 and the Ph.D. degree in August of 1974. He accepted a position as Assistant Professor of Agricultural Economics at the University of Kentucky in September, 1974. He is married to the former Sylvia K. Collier of Union City, Tennessee.