A DYNAMIC MODEL OF PRICES, SUPPLIES, AND REVENUE ADJUSTMENTS IN THE U.S. BEEF MARKET: EMPHASIS ON CHANGING FEED COSTS

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Applied Economics

MONTANA STATE UNIVERSITY
Bozeman, Montana

June 1989

APPROVAL

of a thesis submitted by

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGMENTS

Sincere gratitude is expressed to Dr. John M. Marsh, chairman of my graduate committee, for his thoughtful advice and counsel during the preparation of this thesis.

I also wish to thank the other members of my graduate committee, Drs. Clyde Greer, Michael Frank, and Steve Stauber for providing many useful comments and suggestions while reviewing this thesis.

Finally, I wish to thank my family for their encouragement and support, and for providing me with the tangible and intangible resources I have relied upon to complete this thesis.

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ABSTRACT

Results of past beef research lack concurrence with respect to the effects of federal grain programs and grain market prices on the beef cattle market. This study examines the impact that changes in exogenous factors, particularly feed prices, have on cattle prices and supplies over time. A dynamic econometric model of the U.S. fed and nonfed beef cattle market is formulated using quarterly data from 1973 to 1987. Price and supply equations were estimated for fed cattle, cull cows, nonfed steers and heifers, and feeder cattle placements. The equations were estimated within a rational distributed lag framework characterized by nonstochastic difference equations and autoregressive-moving average error terms. Solved reduced form coefficients were used to calculate short run and long run percentage price and supply responses. In addition, percentage responses were used to simulate revenue adjustments in the beef industry resulting from changes in corn price and the corn loan rate.

The largest short run percentage price and supply responses were associated with by-product value except in the case of cull cow supply where corn price dominated. By-product value generated the largest long run percentage responses in all but the feeder sector and the total nonfed cattle supply sector where corn price demonstrated the larger effects. Interest rate was associated with the smallest short run percentage responses in all cases and the smallest long run responses in all but total nonfed cattle supply. All prices responded inversely to changes in corn price as did fed cattle supply and feeder cattle placements. Cull cow supply, nonfed steer and heifer supply, and total nonfed cattle supply responded positively to changes in corn price.

Fed cattle and feeder cattle sector gross revenues were inversely related to changes in corn price and the corn loan rate, while gross revenues in the nonfed steer and heifer sector and cull cow sector were positively related. The results emphasize the importance of resource trade-offs between cattle finishing and nonfed cattle production; however, they must be interpreted carefully in light of recent structural changes in meat packing.

CHAPTER 1

INTRODUCTION

Studies of the U.S. beef industry have recognized prices of feed grains (corn, barley, sorghum) as important factors in determining beef supplies, demands, and prices. Free market factors and/or government farm policies that alter feed grain prices effectively change the costs of finishing cattle on grain (fed beef) and influence derived demands for stocker and feeder cattle (Buccola, 1979). The result is to directly impact the income levels of cow-calf producers, yearling producers, and cattle feeders through changing cattle prices and input costs. Grain prices also indirectly affect consumers through prices paid for retail beef products (table cuts and processed meat) due to various quantities and qualities of beef supplied.

In addition to feed prices, variables such as consumer income, prices of beef substitutes, interest rates, and marketing costs influence the beef supply, demand, and price structure. The dynamic nature of the beef sector implies that changes in many of these factors result in intertemporal market disturbances. Proper measurement of the impacts can aid producers in marketing decisions by providing better information to formulate expectations about the future.

Statement of the Problem

A comparison of past beef market research shows that not all studies are in agreement concerning the direction and magnitude of changes in cattle prices and marketings subsequent to changes in federal grain programs and grain market prices. Many of the results are summarized in the literature review section. The purpose of this study is to statistically estimate the impact that changes in exogenous factors, particularly feed prices, have on cattle prices and supplies over time. The information generated will increase understanding of the dynamic nature of the cattle sector and its various marketing stages, i.e., cattle grazing (nonfed beef), cattle finishing (fed beef), and slaughtering and processing. The information should also provide a sound basis for evaluating grain policy alternatives with respect to their potential impacts on the cattle industry.

Objectives

There were several objectives of this study. The first objective was to formulate and statistically estimate a seasonal, dynamic econometric model representing the structural and behavioral characteristics of the U.S. fed and nonfed beef cattle industry. The second objective was to estimate short run and long run adjustments in cattle prices and quantities that result from imposing arbitrary exogenous shocks on the industry. The third objective was to simulate industry revenue adjustments to changes in both free market corn price and corn loan rate. The last objective was to evaluate the market adjustment results in light of their economic logic and to assess any subsequent marketing implications in the beef sector.

Procedures

A quarterly multi-equation beef sector model was developed. The model consists of equations for feeder cattle demand and price, slaughter cattle prices by class, and both fed and nonfed cattle supply. Model specification is based on economic theory, prior research, and knowledge of the beef livestock industry. The functions are estimated within a rational distributed lag framework, characterized by nonstochastic difference equations and autoregressive-moving average (ARMA) error terms. Economic theory usually provides little assistance in specifying lag orders; consequently, the dynamics on the endogenous and exogenous variables and ARMA error terms are empirically determined. Simultaneity problems that occur in the dynamic equations are handled by instrumental variables (Hanssens and Liu, 1983). Quarterly time series data from 1973 to 1987 are utilized to estimate the model. Because of nonlinearities in the parameters resulting from the nonstochastic difference equations and/or nonspherical disturbances, least squares estimates of the structural coefficients are calculated by a modified Marquandt nonlinear least squares algorithm (Burt, Townsend and LaFrance, 1986).

Marginal (period-by-period) and cumulative changes in the endogenous variables, subsequent to exogenous shocks, are calculated using a mathematical algorithm that estimates the partial derivatives by solving each difference equation numerically. The estimated partial derivatives permit the calculation of percentage price response and percentage supply response coefficients for various lenths of run. These coefficients aid in analyzing the specific behavior and equilibrium adjustment patterns for prices, supplies, and industry revenues due to changes in the corn loan rate structure.

Literature Review

The literature is comprised of extensive quantitative research on beef demand and supply analysis. However, statistical models have demonstrated various conclusions about the nature of market responsiveness as a result of different units of observation, sample periods, equation specifications (static or dynamic), and quantitative methods employed. Most of the studies have been useful for examining beef market behavior within estimated market structures, yet the measured beef price effects of changes in feed costs have not been homogeneous.

Reutlinger (1966) formulated an annual model to estimate the short run supply elasticity of beef. Beef production data were disaggregated among sex and quality categories. Reutlinger recognized that cows and heifers serve a dual purpose as both capital goods and consumption goods. A lagged beef-corn price ratio variable was included in the supply functions for steers, cows, heifers, and cows and heifers. He found that specifying supply functions for each component of beef slaughter yielded beef-corn price ratio supply elasticities with the expected signs, positive for steers and negative for cows.

Langemeir and Thompson (1967) specified an annual simultaneous equations model of beef supply and demand. The period of analysis was 1947 to 1964. Their model disaggregated beef supply into fed, nonfed, domestic, and import components. Current and lagged corn prices inversely affected the average live weight of fed cattle considerably. The current corn price demonstrated a stronger influence than the lagged price.

Kulshreshtha and Wilson (1972) estimated simultaneous relationships among demand, supply, price, and export variables in the Canadian beef sector. Annual data from the period 1949 to 1969 were used in the analysis. A weak negative relationship was found between beef cattle inventory and the beef-grain index (farm price of beef cattle divided by the index of the price of feed grains). The beef cattle inventory elasticity of supply with respect to the beef-grain index was -0.098. A dressed weight per head elasticity of supply with respect to the beef-grain index was 0.034.

Tryfos (1974) formulated an annual model of the Canadian livestock sector for the years 1951 to 1971. Separate equations for beef supply and inventories of cattle were specified in the model. The focus of the study was the interdependence of livestock supplies and inventories. Meat production responsiveness to price and feed cost changes was also examined. The results were a positive feed cost elasticity of supply for cattle estimated at .024 and a negative own price (average live cattle price) elasticity of supply for cattle estimated at -.009.

Freebairn and Rausser (1975) estimated the effects of changes in the level of U.S. beef imports on the domestic beef industry. An annual simultaneous equation model was specified using data from 1956 to 1971. Beef production was partitioned into fed and nonfed sectors. Farm price of corn entered exogenously into the cattle placed on feed equation. The price of corn was estimated to have a small effect on the number of cattle placed on feed with an elasticity of -0.1. However, the price of corn was not found to be statistically significant in the fed cattle slaughter equation.

Folwell and Shapouri (1977) developed an annual model of the U.S. beef sector for the period 1949 to 1970. The model was partially block recursive but also simultaneous in many structural relationships. The price of corn entered exogenously into the model as a proxy for feed cost in beef production. The impact of a $1.00/bushel increase in the price of corn was to increase the price of beef cattle $1.92/cwt. in the short run and .41/cwt. in the long run. The same increase in corn price also decreased commercial cattle slaughter by 804.5 million pounds liveweight in the short run and 200.8 million pounds liveweight in the long run.

Shuib and Menkhaus (1977) constructed a simultaneous equations model of the beef and feed grain economy. Annual observations over the period 1950 to 1974 were used in the analysis. Beef cattle were disaggregated by quality grade into fed and nonfed beef groups. Corn price was incorporated into the fed beef supply function in the form of a beef-corn price ratio. From estimates of the structural coefficients it was inferred that a one percent increase in the beef-corn price ratio would lead to a .14% increase in fed beef supply. A one percent increase in the ratio would bring about a .12% decrease in nonfed beef production.

Nelson and Spreen (1978) analyzed the dynamic behavior of monthly steer and heifer slaughter. They concluded producers extrapolated recent price trends which led to either delayed or accelerated marketings. This behavior would tend to reinforce the price trend leading up to the decision to delay or accelerate marketings. Feed prices were initially included in the model as explanatory variables, but were later omitted because the relevant parameters varied in sign under alternative model specifications and were usually not statistically significant.

Arzac and Wilkinson (1979) estimated a quarterly and annual disaggregated econometric model of the U.S. livestock and feed grain markets for the years 1960 to 1975. The main purpose of the study was to obtain quarterly forecasts of variables in the livestock-feed sector. Dynamic multipliers were calculated to give the effect of changes in the support price for corn and other exogenous factors on producer and retail prices and acreage planted. The model was stable and capable of sustaining cyclical behavior. It was concluded that corn exports, yield, and consumer income were more important sources of fluctuation in retail and producer prices than was corn support price.

Ospina and Shumway (1979) formulated an annual, simultaneous equations model of U.S. slaughter beef supply. The period of analysis was 1956 to 1975. The study was primarily concerned with conceptual problems of empirically estimating beef supply response. Part of the approach taken to alleviate these problems was to disaggregate slaughter cattle by sex and quality categories. The effects of feed price changes on beef price, supply, and composition were found to be significant. The estimated elasticity of supply of all beef with respect to corn price was -.25. In comparison, the own price elasticity of supply of all beef was .14.

A reduced form model was derived in order to evaluate effects of corn price changes on beef prices based on supply composition. The estimated short run impacts of a $1.00/bushel increase in corn price were to decrease choice beef supply by 2.9 billion pounds and increase good (select) beef supply by 1.2 billion pounds. Overall, the $1.00/bushel increase in corn price decreased current slaughter supply by 1.7 billion pounds. Prices of choice and good (select) beef adjusted to the $1.00/bushel increase by increasing $8.80/cwt. and $6.30/cwt., respectively, over one year.

Ospina and Shumway (1981) also examined the impact of corn price on prices and composition of slaughter beef in a 1981 study. The model developed in the 1979 study was re-estimated with annual data from 1956 to 1978. Beef supply partial elasticities with respect to corn price and average beef price were estimated respectively at -.23 and .15. The most important impacts of an increase in corn price were, in the short run, decreases in choice slaughter marketings and utility beef price. In the long run, sustained increases in corn price decreased choice slaughter marketings and utility beef price and increased utility beef slaughter.

Brester and Marsh (1983) estimated an annual, dynamic model of the primary and derived levels of the U.S. beef sector with rational distributed lags. Examination of the short run nonfed slaughter supply elasticity indicates a 10% increase in the price of corn would result in a 4.2% increase in nonfed slaughter. The long run slaughter supply elasticity implied that the same change in corn price would yield a 9.2% increase in nonfed slaughter.

Marsh (1983) estimated U.S. feeder and fed cattle prices with rational distributed lags and nonstochastic difference equations. The model was found to be an improvement over static-serial correlation and purely autoregressive model specifications. Corn price was statistically significant in the functions. The distributed lag effects of corn price on feeder cattle prices peaked in three quarters and stabilized in about 16 quarters. One result of the analysis was that a $1.00 increase in corn price reduced feeder prices by $7.87/cwt. in the long run.

Marsh (1984) used distributed lags to estimate a quarterly, seasonal model of U.S. hog and cattle supply response. The cattle sector was disaggregated into fed, nonfed and cow slaughter. In the fed steer and heifer slaughter equation the price elasticity of supply was -.15. Contemporaneous corn price was statistically insignificant and therefore omitted from the analysis. However, the lagged quarterly corn price (t-1) had a positive influence on fed slaughter supply with a short run elasticity coefficient of .06.

The nonfed steer and heifer slaughter equation was specified with a steer-corn price ratio variable. Supply elasticities indicated that a 10% increase in the ratio reduced nonfed slaughter by 2% in the short run and 15% in the long run.

Shonkwiler and Hinckley (1985) applied a generalized supply response model to the feeder cattle market. Derived demand for feeder cattle was specified as a function of feeder cattle price, the price of feed (corn), and the expected price of fed cattle. The data consisted of 58 bimonthly observations from February 1972 to August 1981. Feed price was statistically significant in the study, and the elasticity of feeder placement demand with respect to corn price was estimated at -.435.

CHAPTER 2

MODEL DEVELOPMENT AND ECONOMETRIC CONSIDERATIONS

The beef industry in the United States is relatively complex with its many production and marketing institutions. The industry consists of several general areas: cow-calf production, yearling grow-out operations, cattle finishing production, beef slaughtering and processing, and wholesale-retail distribution. Cow-calf producers generally supply weaning age calves to be used in further production by yearling producers who grow-out calves for cattle finishers, stocker operators, or market the yearlings directly to packers. Cattle finishers utilize high energy feed rations to produce fed (or fat) cattle, oftentimes referred to as fed beef. Stocker operators grow-out calves and yearlings primarily on roughages and range forage. Calves and yearlings finished on range that go directly to slaughter, along with cull cows and bulls, are usually referred to as nonfed beef.

Packers slaughter fed and nonfed cattle and process them into wholesale beef which primarily consists of carcass halves (front and hind quarters) and boxed beef. The latter consists of fabricating carcasses into primal, subprimal, and sometimes retail cuts to be vacuum packaged and sold in boxed form (McCoy and Sarhan, 1988). Retailers usually further process subprimal beef into table cuts to be sold to consumers.

Consumer purchases of retail beef are the basis of primary demand in the beef market. Consequently, the demands for wholesale beef, fed and nonfed slaughter cattle, and yearlings and feeder calves are derived from the retail level. The supply of beef originates at the cow-calf producer level. The supplies produced at other levels (yearlings, slaughter cattle, and wholesale and retail beef) are derived from the primary level in a manner similar to the demand side. The supply of and demand for beef at each stage determines the price at each market level. Differences between the prices at the various levels are referred to as marketing margins.

Marketing margins are essentially composed of the time, space, and form costs of converting a raw product or input into intermediate products and ultimately a finished product (Tomek and Robinson, 1981). Figure 1 represents marketing margins for a fixed quantity of beef marketed, Q^*, where Q^* is defined on a retail weight equivalent basis (Tomek and Robinson, 1981). Marketing margin M1 in Figure 1 represents the difference between a feedlot operator's output price (price of slaughter cattle) and input price (price of feeder cattle). M1 exists because feedlot operators must purchase feed and non-feed inputs in order to convert feeder cattle into fed steer and heifer outputs. The marketing margin M2 represents the slaughtering and processing margin for meat packers, while M3 represents the wholesale-retail marketing price spread. Under conditions where the marketing margins would be relatively static, fluctuations in derived demand and derived supply mainly originate from changes at the primary levels and factors specific to the derived markets. However, a marketing margin

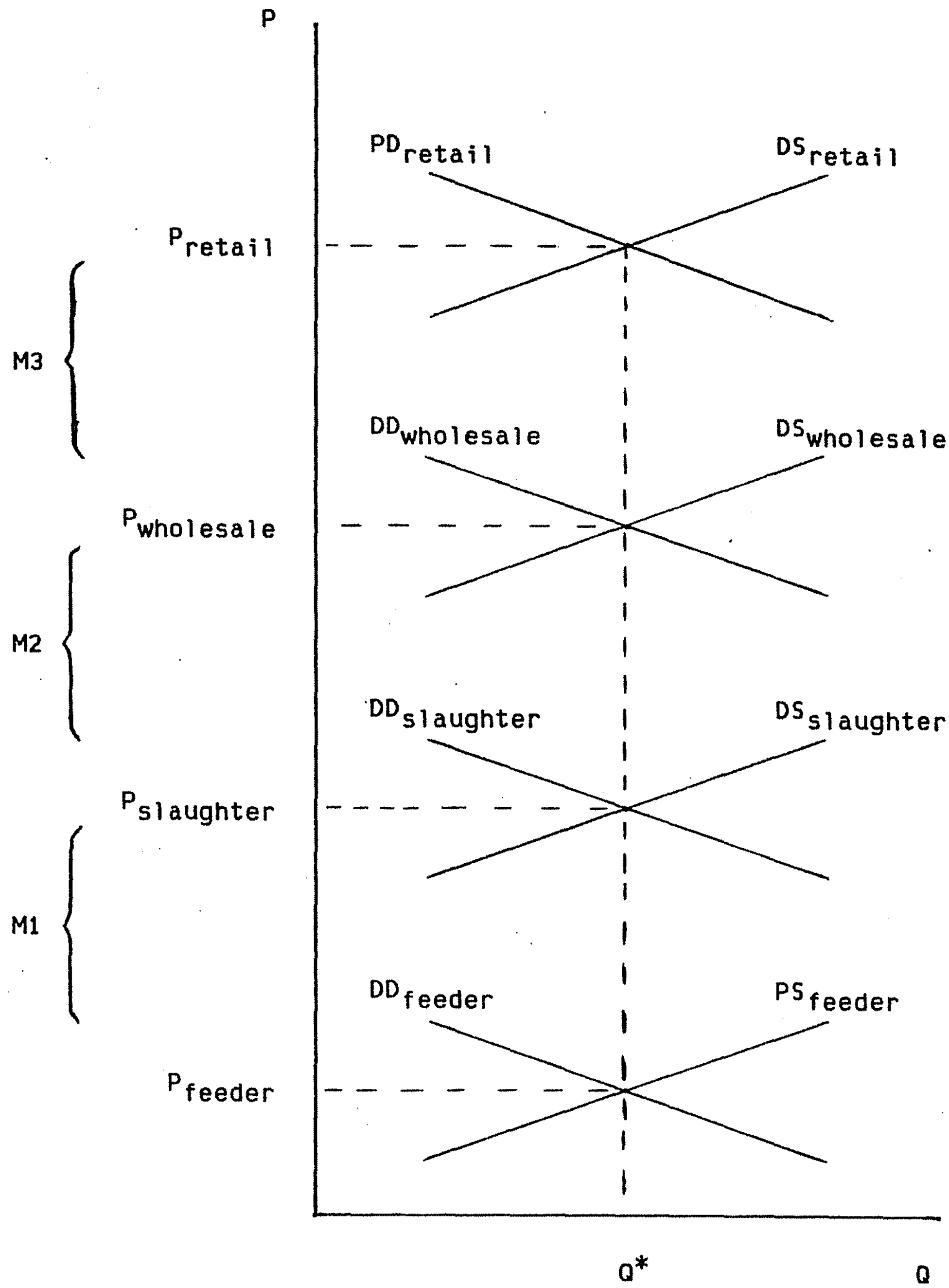

Figure 1. Primary and derived supply and demand relationships and marketing Margins.

is subject to change because of changes in factors that affect the prices of inputs used to transform products at a specific market level. Since margins link the various beef marketing stages, changes in supply and/or demand curves at one level impact supply and demand at other levels; the magnitude of the latter depends upon the relevant supply and demand elasticities and the nature of marketing margins themselves (Tomek and Robinson, 1981).

The above general characteristics of the beef market play an important role in specifying the demand, supply, and price equations of the model. The remainder of this chapter is concerned with the specification and justification of the variables in each equation followed by a discussion of econometric considerations.

Specification of Economic Model

The beef model is segregated into fed and nonfed sectors, consisting of inverse demand (price) and market supply equations specific to the live cattle trade. The sectors are delineated as the feeder cattle market, fed cattle market, cull cow market, and nonfed steer and heifer market.

Feeder Price and Placements

The feeder cattle sector is represented by feeder steer price and cattle placed on feed. They are given as:

$$PFEED_t = f_1(Dbar, PLAC_{t-i}, PCORN_{t-i}, INT_{t-i}, PFED_{t-i}, PFEED_{t-j}) \quad (2.01)$$

$$PLAC_t = f_2(Dbar,\ PFEED_{t-i},\ PFED_{t-i},\ PCORN_{t-i},\ INT_{t-i},\ PLAC_{t-j}) \qquad (2.02)$$

$i = 0,1,\ldots,p \qquad j = 1,2,\ldots k \qquad p \leq k$

where

PFEED = Price of medium frame, #1, 600-700 lb. feeder steers, Kansas City ($/cwt.).

PLAC = Net placements of cattle on feed for 13 states (thousands of head).

PCORN = Price of #2 yellow corn, Omaha ($/bu.).

INT = Production Credit Association interest rate (percent).

PFED = Price of choice, yield grade 2-4 slaughter steers, 900-1100 lbs., Omaha ($/cwt.).

Dbar = Seasonal dummy variables for calendar quarters of the year. D1 = 1st quarter (omitted from equation), D2 = 2nd quarter, D3 = 3rd quarter, D4 = 4th quarter.

All price and interest rate variables are adjusted by the consumer price index (1967=1.0). The price of feeder steers is specified as a function of binary variables, cattle placements, corn price, interest rate, price of fed cattle and lagged feeder price. Feeder placements are specified as a function of binary variables, price of feeder steers, price of fed steers, corn price, interest rate and lagged placements.

The expected marginal impacts of the variables are given by the signs of the partial derivatives in the PFEED and PLAC equations. They are given as:

$\partial PFEED/\partial PLAC > 0$

$\partial PFEED/\partial PCORN < 0$

$\partial PFEED/\partial INT < 0$

$\partial PFEED/\partial PFED > 0$

$\partial PLAC/\partial PFEED < 0$

$\partial PLAC/\partial PFED > 0$

$\partial PLAC/\partial PCORN < 0$

$\partial PLAC/\partial INT < 0$

Placements of cattle on feed and feeder price are assumed to be jointly dependent. Therefore, if cattle feeders demand more (less) feeder placements there would be a simultaneous increase (decrease) in feeder cattle price given an inelastic supply of feeders. Corn price is used as a proxy for grain concentrate costs since corn is the major feed input in U.S. fed cattle production. Increases in feed costs are expected to decrease both feeder placement demand and feeder price since cattle feeding returns would be reduced (Buccola, 1979). Interest rates represent an opportunity cost on the capital invested in purchasing feeder cattle, feed, and other cost items necessary in the finishing process. Interest rate is expected to have an inverse effect on feeder placement demand and feeder prices since its increase (decrease) would decrease (increase) returns to cattle finishing. Fed cattle price reflects the output price of the finished product for cattle feeders. Other variables constant, higher fed cattle price increases finishing returns, which is a profit incentive for cattle finishers to demand more cattle placements, resulting in higher prices of feeder cattle.

Fed Price and Supply

The following equations represent the price of fed cattle and fed cattle marketings:

$$PFED_t = f_3(Dbar,\ QFED_{t-i},\ TOTNF_{t-i},\ QHOGS_{t-i},\ QPOULT_{t-i},\ BPV_{t-i},\ Y_{t-i},\ PFED_{t-j}) \quad (2.03)$$

$$QFED_t = f_4(\ Dbar,\ PLAC_{t-i},\ QFED_{t-j}) \quad (2.04)$$

$i = 0,1,\ldots,p \qquad j = 1,2,\ldots,k \qquad p \le k$

where

PFED = Price of choice, yield grade 2-4 slaughter steers, 900-1100 lbs., Omaha ($/cwt.).

QFED = Quantity of fed cattle marketings, 13 states (thousands of head).

TOTNF = Total nonfed cattle marketings including steers, heifers, cows, bulls and stags, 13 states (thousands of head).

QHOGS = Commercial hog slaughter (thousands of head).

QPOULT = Total production of young chickens and turkeys (millions of lbs.).

BPV = Total by-product value per 1000 lb. steer ($/cwt.).

Y = Personal disposable income (billions of dollars).

PLAC = Net placements of cattle on feed, 13 states (thousands of head).

Dbar = Seasonal dummy variables (defined previously).

The equations indicate that the price of fed steers is a function of binary variables, fed cattle marketings, total nonfed cattle marketings, hog slaughter, poultry slaughter, by-product values, and lagged fed steer price. The supply of fed cattle is specified as a function of binary variables, feeder cattle placements, and lagged fed cattle marketings. The binary variables in both the fed price and fed supply equations are specified to account for marketing patterns that are seasonal in nature, reflected by shifts in the intercepts.

The expected responses of fed price and fed supply to changes in the independent variables are given by the signs of the partial derivatives:

$\partial PFED/\partial QFED < 0$

$\partial PFED/\partial TOTNF < 0$

$\partial PFED/\partial QHOGS < 0$

$\partial PFED/\partial QPOULT < 0$

$\partial PFED/\partial BPV > 0$

$\partial PFED/\partial Y > 0$

$\partial QFED/\partial PLAC > 0$

Changes in fed cattle supplies are expected to inversely impact fed cattle price since a downward sloping slaughter demand schedule implies larger supplies of fed cattle would be purchased by meat packers only at lower prices. Total nonfed cattle supplies would also inversely affect fed slaughter price since they are a lower grade of beef that substitutes for fed beef at the retail level. Hog slaughter and poultry slaughter are included as regressors since they are substitutes for fed beef at the retail level. A priori, changes in their production levels are expected to inversely affect fed price at the slaughter level of the market. By-product values are an important determinant of fed cattle price since packers often rely on sales of by-products to cover their slaughter costs and profit margins (Ward, 1980). A priori, increases in by-product values would be an incentive for packers to demand more slaughter cattle, thus leading to an increase in slaughter price. Income represents consumer purchasing power at the retail level. Assuming fed beef to be a normal good, increases in income would increase fed beef consumption, hence, increase the derived demand for fed slaughter cattle and fed cattle price.

The intertemporal nature of cattle feeding suggests that the quarterly supply of fed cattle should be specified as a function of current and previous quarter placements of cattle on feed. This relationship is used by the USDA in forecasting seasonal fed slaughter, and indirectly reflects the economic arguments in the cattle placement function. The relationship is expected to be positive since placing cattle on feed results in marketing slaughter cattle after the finishing periods have been completed.

Cull Cow Price and Supply

The cull cow sector is represented by the following price and supply equations:

$$PCOW_t = f5(\, Dbar,\ QFED_{t-i},\ TOTNF_{t-i},\ BPV_{t-i},\ Y_{t-i},\ PCOW_{t-j}) \qquad (2.05)$$

$$QCOW_t = f6(\ Dbar,\ PFEED_{t-i},\ PCOW_{t-i},\ QCOW_{t-j}) \qquad (2.06)$$

$i = 0,1,\ldots,p \qquad j = 1,2,\ldots k \qquad p \le k$

where the variables are defined as follows:

PCOW = Price of utility cows, yield grades 2-3, all weights, Omaha ($/cwt.).

QFED = Quantity of fed cattle marketings for 13 states (thousands of head).

TOTNF = Total nonfed cattle marketings, steers, heifers, cows, bulls and stags for 13 states (thousands of head).

BPV = Total by-product value per 1000 lb. steer ($/cwt.).

Y = Personal disposable income (billions of dollars).

QCOW = Commercial cow slaughter for 13 states (thousands of head).

PFEED = Price of medium frame #1 feeder steers, 600-700 lbs., Kansas City ($/cwt.).

Dbar = Seasonal dummy variable (defined previously).

The price of cull cows is specified as a function of binary variables, quantity of fed cattle marketings, total nonfed marketings, by-product value, income, and lagged cow price. The quantity of cow marketings (slaughter supply) is specified as a function of binary variables, feeder price, cow price, and lagged cow marketings.

The expected signs of the partial derivatives for the independent variables in the cow price and supply equations are:

$\partial PCOW/\partial QFED < 0$

$\partial PCOW/\partial TOTNF < 0$

$\partial PCOW/\partial BPV > 0$

$\partial PCOW/\partial Y > 0$

$\partial QCOW/\partial PFEED < 0$

$\partial QCOW/\partial PCOW > 0$

Other variables constant, total nonfed marketings are expected to have an inverse effect on the price of cows, i.e., increases in nonfed supply (demand unchanged) would be purchased by packers at reduced slaughter prices. One important component of total nonfed marketings is cull cow slaughter. Cull cow slaughter was aggregated with the other nonfed variables in order to reduce the collinearity problem from its separate lag specification. Cow price is expected to be positively correlated with by-product value since by-products from the slaughter process are an important component of total packer returns. The sign of the income effect through the derived demand process is uncertain. Income could exert a positive impact on the price of cows if increases in income lead to higher fed cattle and feeder cattle prices that result in an increase in the demand for cows as capital goods. However, a negative sign could be possible since cull cow beef is of lower quality than Choice grade beef. Thus, if a negative income effect was associated with processed beef and lower grade table cuts, the derived demand (hence price) for cull cows could decline subsequent to an increase in income.

The quantity of cull cow slaughter is expected to be negatively influenced by feeder cattle price. Cow-calf and cow-yearling operators produce feeder cattle by using breeding cows (capital assets) as a major input. If feeder cattle price increases and feeder cattle producers do not view this as merely a temporary change, the result could lead to a build-up of beef cow herds. The increase in herds would, in part, be accomplished by decreasing the amount of cull cow slaughter.

Cull cow slaughter is also expected to respond to changes in cow price since the latter represents the salvage value of a capital asset. A priori, with increases in cull cow prices, marketings would be expected to increase as feeder cattle producers recognize an opportunity to increase their cash flows by culling additional cows from the herd.

Nonfed Price and Supply

The following equations represent the price of nonfed steers and the supply of nonfed steers and heifers:

$$PGOOD_t = f_7(\, Dbar,\ QFED_{t-i},\ TOTNF_{t-i},\ BPV_{t-i},\ Y_{t-i},\ PGOOD_{t-j}) \qquad (2.07)$$

$$QNFSH_t = f_8(\, Dbar,\ PLAC_{t-i},\ QNFSH_{t-j}) \qquad (2.08)$$

$$i = 0,1,\ldots,p \qquad j = 1,2,\ldots k \qquad p \leq k$$

where

PGOOD = Price of Select slaughter steers, yield grade 2-3, 900-1100 lbs., Omaha ($/cwt.).

QFED = Quantity of fed cattle marketings, 13 states (thousands of head).

TOTNF = Total nonfed cattle marketings including steers, heifers, cows, bulls and stags, 13 states (thousands of head).

BPV = Total by-product value per 1000 lb. steer ($/cwt.).

Y = Personal disposable income (billions of dollars).

QNFSH = Nonfed steer and heifer slaughter for 13 states (thousands of head).

PLAC = Net placements of cattle on feed for 13 states (thousands of head).

Dbar = Seasonal dummy variable (defined previously).

Steers and heifers finished on high roughage rations and/or range forage are generally lower quality beef (than Choice) and usually grade Select (formerly Good) or lower. In the nonfed price equation the price of Select grade steers is chosen as the dependent variable and is specified as a function of binary variables, fed marketings, total nonfed marketings, by-product value, personal disposable income, and the lagged dependent variable. The supply of nonfed steers and heifers is determined by binary variables, cattle placements on feed, and the lagged dependent variable.

The partial derivatives of the functions with respect to the independent variables and their expected signs are given as:

$\partial PGOOD/\partial QFED < 0$

$\partial PGOOD/\partial TOTNF < 0$

$\partial PGOOD/\partial BPV > 0$

$\partial PGOOD/\partial Y > 0$

$\partial QNFSH/\partial PLAC < 0$

Higher quality fed beef (QFED) is considered to be a close substitute for nonfed beef and is therefore specified in the Select slaughter price equation. A priori, an increase in the supply of fed beef would decrease the price of Select grade steers. Total nonfed marketings represent a direct effect in the market for lower grade beef and are expected to have an inverse impact on Select price. The importance that packers place on the value of by-products for covering their slaughtering costs and profit margins suggests Select steer price should (like Choice steer price) be positively affected by changes in by-product value. Retail beef processed from nonfed beef carcasses is generally viewed as lower quality beef. Thus, depending upon whether nonfed beef is considered to be an inferior or normal good, increases in income are expected to have a negative or positive effect, respectively, on the price of Select steers.

The quantity of nonfed steer and heifer slaughter is expected to be sensitive to changes in placements of cattle on feed because of the important trade-off between steers and heifers allocated to fed and nonfed production. For example, with a given cattle inventory base, increases (decreases) in feeder placements are expected to decrease (increase) the quantity of nonfed steer and heifer slaughter. These shifts occur as the relative profitabilities between cattle feeding and cattle grazing for slaughter purposes change.

Total Nonfed Supply

The following equation represents the supply of total nonfed slaughter:

$$TOTNF_t = f_9(Dbar, PLAC_{t-i}, PFEED_{t-i}, PCOW_{t-i}, TOTNF_{t-j}) \quad (2.09)$$

$$i = 0,1,\ldots,p \qquad j = 1,2,\ldots,k \qquad p \leq k$$

where

TOTNF = Total nonfed cattle slaughter of steers, heifers, cows, bulls and stags for 13 states (thousands of head).

PLAC = Net placements of cattle on feed, 13 states (thousands of head).

PFEED = Price of medium frame #1, 600-700 lb. feeder steers, Kansas City ($/cwt.).

PCOW = Price of #2-3 utility cows, all weights, Omaha ($/cwt.).

Dbar = Seasonal dummy variable (defined previously).

The major components of total nonfed marketings are nonfed steers and heifers and cull cows, while bulls and stags constitute only a minor portion. However, the components are aggregated since this is the form of the variable as a regressor in previous equations. The equation for total nonfed marketings is hypothesized to be a function of seasonal binaries, feeder cattle placements, feeder price, cow price, and the lagged dependent variable.

The expected signs of the partial derivatives for the independent variables are given as:

$\partial TOTNF/\partial PLAC < 0$

$\partial TOTNF/\partial PFEED < 0$

$\partial TOTNF/\partial PCOW > 0$

Cattle placements is specified as a regressor in order to include the trade-off between the fed and nonfed beef sectors. If placements increase, a smaller proportion of available feeder steers and heifers go into the nonfed sector which would decrease total nonfed slaughter. The price of feeder steers represents the opportunity cost of nonfed cattle production. For example, increases in feeder price provide more of an incentive to offer young cattle for cattle finishing purposes; thus, the result would be a decrease in total nonfed slaughter. The opportunity cost of owning cows is given by the price of cull cows and the variable is expected to be positively correlated with total nonfed marketings. For example, an increase in cow price would increase cull cow slaughter and thereby increase total nonfed slaughter.

Econometric Considerations

The explanatory variables included in the above model are hypothesized to have dynamic impacts on the dependent variables. Thus, lagged explanatory variables (as given by the subscript lag notations) are used to account for adjustment processes of the dependent variables that may be distributed over several time periods. The lags in adjustment usually occur because of the presence of market rigidities such as technical and biological constraints, imperfect knowledge, and buyer and seller expectations.

Such adjustments form the basis of distributed lag theory. This theory, when embodied in dynamic models, attempts to describe the time response nature of an endogenous variable to either a transitory or permanent shock in an exogenous variable.

The following equation illustrates a relatively simple distributed lag structure:

$$Y_t = B_0X_t + B_1X_{t-1} + B_2X_{t-2} + \ldots + e_t \qquad (2.10)$$

where the disturbance term e_t is white noise. Such an equation represents an infinite distributed lag impact of the variable X on Y; however, the structure encompasses some major problems. One problem is that the number of parameters in the model do not allow sufficient degrees of freedom for estimation, i.e., there are an infinite number of parameters and a finite sample. Truncating the lagged X's at some maximum lag length can be arbitrary since there may be little a priori information to suggest when the lagged effects dissipate. If the model is estimated with a large (finite) lag length, the asymptotic t tests may give an indication of lag significance. However, such tests are influenced by the nature of the disturbance term, i.e., spherical or nonspherical properties, and the likelihood that a high degree of multicollinearity may exist between the lagged X's (Johnston, 1984).

Koyck formulated a series of geometric weights to handle the infinite lag problem. Under Koyck's scheme, the B's in equation (2.10) are assumed to decrease exponentially over time given by the parameter weights:

$$B_i = B_0\lambda^i \qquad i = 0,1,2,.... \tag{2.11}$$

where B_0 is a fixed parameter and $0< \lambda <1$. Substituting (2.11) into (2.10) and applying the Koyck transformation results in the following equation (Kmenta, 1986):

$$Y_t = B_0X_t + \lambda Y_{t-1} - e_t - \lambda e_{t-1} \tag{2.12}$$

Equation (2.12) is reduced to a first order difference equation with a first order moving-average (MA) error process. Ordinary least squares estimation of (2.12) produces biased and inconsistent estimates of the parameters due to the correlation between Y_{t-1} and the error process. Consistent estimates of the coefficients under the assumption of normally distributed disturbances can be obtained using instrumental variables or maximum likelihood methods (Kmenta, 1986).

The Koyck lag is a special case of the more general rational distributed lag function introduced by Jorgenson (1966). The rational distributed lag model can be formulated mathematically as:

$$Y_t = W(L)X_t = A(L)/B(L)X_t + e_t \tag{2.13}$$

where e_t is white noise and $E(X_t e_t) = 0$. W(L) has a rational generating function characterized by the ratio of two polynomials, A(L) and B(L), which have no characteristic roots in common. L is a lag operator notation such that $L^k X_t = X_{t-k}$. The polynomial A(L) is of order m in the lag operator specific to the independent variable, while B(L) is of order n in the lag operator specific to the dependent variable and the error term.

Specifically, A(L) and B(L) are given as:

$$A(L) = a_0 + a_1 L + a_2 L^2 + \ldots + a_m L^m \tag{2.14}$$

$$B(L) = 1 - B_1 L - B_2 L^2 - \ldots - B_n L^n \tag{2.15}$$

with B_0 normalized at 1.0. Expanding equation (2.13) under the lag operator concept results in the distributed lag equation:

$$Y_t + b_1 Y_{t-1} + \ldots + b_n Y_{t-n} = a_0 X_t + a_1 X_{t-1} + \ldots + a_m X_{t-m} + b_1 e_{t-1} + \ldots + b_n e_{t-n} + e_t, \tag{2.16}$$

which results in an nth order stochastic difference equation with an nth order MA error process. If an error term is not originally included in equation (2.13), it may be added to equation (2.16) and freely estimated as an autoregressive-moving average (ARMA) process (Rucker, Burt, and LaFrance, 1984). Jorgenson (1966) showed that a rational lag equation is a flexible function that can approximate any arbitrary distributed lag to any desired degree of accuracy given sufficiently large values of m and n.

A priori specification of m and n in the polynomial lag operators is difficult when using rational lags. Usually economic theory provides little information about the true orders of m and n (knowledge of the commodity market may provide some information); thus, they are often empirically determined. Sometimes the empirical search is complicated by dynamic instability, which occurs when the roots of the difference equation lie inside the unit circle boundary (Griliches, 1967). This instability may reflect factors such as data problems and/or specification errors in the regression mean, i.e., omitted variables.

A common problem inherent with rational lags is statistical correlation between the composite error structure and the lagged dependent variables. The problem is particularly acute for stochastic difference equations such as (2.13), and results in biased and inconsistent parameter estimates if estimated by OLS. One procedure available to handle the error structure-lagged dependent variable correlation problem is nonstochastic difference equations (Burt, 1978). With nonstochastic difference equations the lagged dependent variables enter the regression as unobserved lagged expectations. This approach ensures consistent estimates of the parameters (even if the disturbance structure is misspecified) since the disturbance process is divorced from the mean of the regression. Burt indicates that nonstochastic difference equations are applicable to rational lags; a simple example is demonstrated with the Koyck lag:

$$Y_t = B_0 X_t + \lambda E(Y_{t-1}) + u_t \tag{2.17}$$

where $E(Y_{t-1})$ is the lagged expected value of the dependent variable and u_t may represent an autoregressive-moving average (ARMA) process. Equation (2.17) is nonstochastic in that it yields the mean of the regression as strictly a function of the historical values of X. $E(Y_{t-1})$ is independent of the disturbance process even if the disturbance term is of an ARMA nature; thus, the parameters of the systematic error structure and mean of the regression are asymptotically uncorrelated.

Introducing lagged expectations of the dependent variable and/or autocorrelated disturbances results in nonlinearities in the parameters, consequently rendering the OLS estimation technique inappropriate. In this model, consistent least squares estimates are obtained by using a modified Marquardt nonlinear least squares algorithm.

Hanssens and Liu (1983) point out that in a rational lag structure the contemporaneous values of certain regressors may be endogenous, thus creating the problem of joint dependency within a dynamic structure. To handle this problem in the beef model, all contemporaneous right-hand-side variables hypothesized as being correlated with their respective error terms were estimated as instrument variables. The procedure was to estimate a set of reduced form equations for the jointly endogenous variables and then substitute the predicted for the observed values in the right-hand-side of structural equations. Theoretically, the predicted values are asymptotically uncorrelated with the disturbance terms permitting consistent and asymptotically efficient estimators.

CHAPTER 3

EMPIRICAL RESULTS

This chapter presents the regression results of the nine equation model specified in Chapter 2. The statistical results are summarized by market sector in Tables 1, 3, 5, and 7. Tables 2, 3, 6, and 8 present the estimated price and supply percentage responses of the rational lag structure. These responses are based on a set of reduced form coefficients solved from the structural equations (Appendix C), and are calculated with respect to three exogenous variables: corn price, by-product value, and interest rate. Simulated adjustments of beef industry gross revenues resulting from free market and corn loan rate changes are presented in the final section of this chapter.

In the final analysis, some of the equations were modified since certain variables were omitted due to lack of statistical significance. The selection of final equations was based on the joint criteria of adjusted R-squared's, standard error of estimates, and asymptotic t-ratios. Variables (excluding the seasonal binaries) whose coefficients had asymptotic t-ratios less than 1.0 were omitted. This was somewhat of an arbitrary cutoff point since a t-ratio of 1.0 represented a significance level of $\alpha \equiv .30$. Variables with t-ratios in excess of 1.0 were retained because of theoretical reasoning and in some cases their joint inclusion improved the fits of the rational lag equations. The order of rational lags for each function was determined by initially estimating the model as first order difference equations with first order lags on the independent variables and an ARMA(1,1) process. The asymptotic t-ratios of the estimated coefficients, along with regression fit, then assisted in either augmenting or truncating the distributed lag structure.

Feeder Cattle Sector

The price of feeder cattle was estimated as a first order nonstochastic difference equation with a first order autoregressive-moving average (ARMA) error (Table 1). Only the contemporaneous values of the independent variables were retained, except the contemporaneous interest rate variable which was omitted because of statistical insignificance. The final feeder price equation yielded asymptotic t-values for coefficients of corn price, fed cattle price, and lagged expected feeder cattle price that were statistically significant at the 95% probability level. The coefficient of the instrument variable, feeder cattle placements, was significant at the 80% level.

The signs of the estimated coefficients are consistent with economic expectations about the impact of the independent variables on feeder price. Specifically, since cattle feeders operate on a feeder-fat cattle margin spread, feeder price is inversely related to the price of corn and positively related to the price of fed cattle (Buccola, 1979). Feeder cattle placements is endogenous and therefore was replaced by its instrument variable (see Appendix B). The sign of the coefficient of feeder placements is positive as previously

Table 1. Statistical Results for the Quarterly Feeder Price and Placement Equations.[a]

		<------	------	------	------	------	Variables[b]	------	------	------	------	------>
Equation	Constant	D2	D3	D4	$\widehat{PLAC}$[c]	PCORN	$\widehat{PFED}$	$\widehat{PFEED}$	INT	E(DEP-1)[d]	AR	MA
PFEED	-5.247	-.900	-1.703	-2.251	.001	-3.737	.730			.556	.429	-.388
	(-1.653)	(-1.526)	(-2.148)	(-1.792)	(1.407)	(-3.956)	(6.299)			(7.310)	(2.281)	(-2.017)
PLAC	.408	1368.800	1822.100	2781.300		-742.330	108.500	-71.642	-38.382	.799		.215
	(.001)	(4.556)	(7.272)	(9.388)		(-5.597)	(5.595)	(-6.304)	(-3.621)	(8.292)		(1.343)

[a]The asymptotic t-ratios are given in parentheses under each coefficient. The critical boundary is 2.010 for a 95 percent probability level.

[b]Regression test statistics are defined as: $\bar{R}^2$ = adjusted R-squared, Sy = standard error of the estimate, and DW = Durbin-Watson statistic. The test statistics for each equation are: PFEED, $\bar{R}^2$ = .933, Sy = 1.674, DW = 1.976; PLAC, $\bar{R}^2$ = .785, Sy = 432.485, DW = 1.681.

[c]A ^ signifies that predicted values of the appropriate variable were substituted for observed values.

[d]E(DEP-1) = the lagged expectation of the appropriate dependent variable.

hypothesized. This result may be attributed to the joint dependency relationship between feeder price and placements, where an increase in the demand for cattle placements is manifested by an increase in feeder price.

Feeder cattle placement was estimated as a first order nonstochastic difference equation with significant coefficients on the contemporaneous values of corn price, fed cattle price, feeder cattle price, and interest rate (Table 1). The autoregressive component of the error term was statistically insignificant; consequently, only the MA(1) component was retained. All the contemporaneous independent variables (excluding the MA term) were statistically significant at the 95% probability level.

The demand for feeder placements, like feeder price, is influenced by economic variables important to a cattle feeding operation. The signs of the estimated coefficients specific to the independent variables are consistent with theoretical reasoning and knowledge of feeder market behavior. The statistical results are: (1) an increase in corn price reduces the demand for feeder cattle, (2) increased fed cattle price increases the demand for feeder placements, (3) increases in feeder price reduces the quantity demanded of feeder placements, and (4) increased interest rates reduce the demand for feeder cattle due to higher costs of purchasing feeders and carrying cattle on feed.

The percentage responses of feeder price and cattle placements to changes in corn price, by-product price, and interest rate for various lenths of run are presented in Table 2. For discussion purposes, in this table and all ensuing percentage response tables, the lengths of run considered are one, two, four, and eight quarters and the long run. For feeder price all response coefficients are less than unity regardless of the time period considered. Specifically, the results denote that a 10% increase in the price of corn would decrease the price of feeder cattle 1.9% in one quarter, 2.9% in two quarters, and 3.9% in the long run. A 10% increase in by-product value would increase feeder price by 4.0% in one quarter, with a long run effect of about 3.1%. The effect of interest rate was considerably less than that of corn price and by-product value. For example, a 10% increase in the interest rate decreases feeder price 0.1% in the short run (one quarter) and 0.3% in the long run. Part of the reason for its relatively small impact is that interest costs constitute only 3-4% of total variable costs of cattle finishing.

The percentage responses for feeder placement demand follow a pattern similar to feeder price in that they are also less than unity. This result occurs primarily because of the jointly dependent nature of the two variables. However, the ranking of percentage effects is somewhat different. Corn price effects elicit the largest percentage response in the long run, followed by interest rate and then by-product price. For example, a 10% increase in corn price will decrease placements of feeder cattle 1.0% in the short run and 4.1% in the long run. A 10% increase in interest rates will cause a 0.6%

decline in short run feeder placements and a 2.4% decline in the long run, while a 10% increase in by-product value would increase placements 1.3% in the short run and 2.0% in the long run.

Table 2. Partial Derivatives and Percentage Price and Placement Responses in the Feeder Cattle Sector.[a]

	Quarters				
Equation	1	2	4	8	Long run
∂PFEED/∂PCORN	-4.192 (-.190)	-6.364 (-.288)	-8.071 (-.365)	-8.652 (-.391)	-8.697 (-.393)
∂PLAC/∂PCORN	-455.880 (-.095)	-806.000 (-.168)	-1281.400 (-.267)	-1727.200 (-.359)	-1965.000 (-.409)
∂PFEED/∂BPV	4.250 (.396)	3.779 (.352)	3.408 (.318)	3.282 (.306)	3.272 (.305)
∂PLAC/∂BPV	293.030 (.126)	333.720 (.143)	388.940 (.167)	440.670 (.189)	468.200 (.201)
∂PFEED/∂INT	-.037 (-.012)	-.056 (-.019)	-.071 (-.024)	-.076 (-.025)	-.076 (-.026)
∂PLAC/∂INT	-36.868 (-.057)	-65.171 (-.100)	-103.580 (-.159)	-139.560 (-.215)	-158.710 (-.244)

[a]The top figures are partial derivatives and the figures in parentheses are percentage responses (calculated at the mean values of the variables). These figures represent the cumulative effects over the indicated number of quarters.

Fed Cattle Sector

The price of fed cattle was estimated as a first order nonstochastic difference equation with contemporaneous fed slaughter, nonfed slaughter, by-product value, and disposable income specified as independent variables (Table 3). Lagged values of the independent

Table 3. Statistical Results for the Quarterly Fed Price and Supply Equations.[a]

Equation	Constant	D2	D3	D4	$\widehat{QFED}$[c]	$\widehat{TOTNF}$	BPV	BPV-1	Y	$\widehat{PLAC}$-1	E(DED-1)[d]	AR
	Variables[b]											
PFED	23.719	-.228	-.894	-1.402	-.002	-.001	5.425	-3.412	-.008		.652	.340
	(1.663)	(-.280)	(-1.052)	(-1.582)	(-1.720)	(-1.675)	(5.710)	(-2.354)	(-1.025)		(2.922)	(2.774)
QFED	393.230	61.109	258.280	-150.220						.323	.648	.138
	(1.205)	(.322)	(1.595)	(-.962)						(5.278)	(8.118)	(1.072)

[a]The asymptotic t-ratios are given in parentheses under each coefficient. The critical boundary is 2.010 for a 95 percent probability level.

[b]Regression test statistics are defined as: $\bar{R}^2$ = adjusted R-squared, Sy = standard error of the estimate, and DW = Durbin-Watson statistic. The test statistics for each equation are: PFED, $\bar{R}^2$ = .878, Sy = 1.737, DW = 1.987; QFED, $\bar{R}^2$ = .666, Sy = 256.739, DW = 2.007.

[c]A ^ signifies that predicted values of the appropriate variable were substituted for observed values.

[d]E(DEP-1) = the lagged expectation of the appropriate dependent variable.

variables, except a first order lag on by-product price, were not statistically significant and were not retained in the equation. The moving average component of the error term was not statistically significant, thus leaving a first order autoregressive error structure.

The hog slaughter and poultry slaughter variables specified in the maintained hypothesis had asymptotic t-ratios less than 1.0 and were omitted. Other variables included in the final specification were the instrumental variables for both fed marketings and total nonfed marketings (significant at the 90% probability level) and personal disposable income (significant at less than the 80% probability level). Income was the only variable in the equation to carry a sign different from theoretical expectations, i.e., a negative income effect on the price of fed beef compared to a hypothesized positive income effect. The negative sign remained unchanged with alternative specifications of the function. A major reason for the result may be the specific data characteristics since there was a negative trend between real fed price and real disposable income.

The fed price percentage responsiveness to changes in corn price, by-product price, and interest rate are presented in Table 4. The most important impact occurs from by-product value changes, while changes in the remaining variables cause relatively small fed price responses. For example, a 10% rise in corn price decreases the price of fed cattle 0.1% in the short run and 0.2% in the long run. A 10% increase in interest rate decreases fed cattle price by 0.04% in the short run and 0.1% in the long run. The stronger effect of by-product value is demonstrated in that a 10% increase in by-product value increases fed cattle price by 5.4% in the short run and 6.0% in the long run. The small effects of corn price and interest rate indicate cattle feeders primarily adjust their feeding margins by changing the price of feeder cattle, and that corn price and interest rates indirectly affect slaughter price through changes in fed and nonfed cattle marketings. As will be seen in the discussions following, these two sectors respond in opposite directions.

Table 4. Partial Derivatives and Percentage Price and Supply Responses in the Fed Cattle Sector.[a]

	Quarters				
Equation	1	2	4	8	Long run
∂PFED/∂PCORN	-.128 (-.006)	-.212 (-.010)	-.305 (-.015)	-.364 (-.017)	-.377 (-.018)
∂QFED/∂PCORN	--- ---	-191.640 (-.035)	-396.290 (-.072)	-518.310 (-.095)	-544.430 (-.099)
∂PFED/∂BPV	5.507 (.542)	5.690 (.560)	5.892 (.580)	6.019 (.593)	6.049 (.596)
∂QFED/∂BPV	--- ---	99.102 (.037)	204.820 (.077)	267.730 (.101)	281.140 (.106)
∂PFED/∂INT	-.010 (-.004)	-.017 (-.006)	-.025 (-.009)	-.029 (-.010)	-.031 (-.011)
∂QFED/∂INT	--- ---	-9.905 (-.013)	-20.471 (-.028)	-26.758 (-.036)	-28.099 (-.038)

[a]The top figures are partial derivatives and the figures in parentheses are percentage responses (calculated at the mean values of the variables). These figures represent the cumulative effects over the indicated number of quarters.

The quantity of fed cattle marketings was estimated as a first order nonstochastic difference equation with an AR(1) error structure (Table 3). The main independent variable, feeder cattle placements, was statistically significant with a one period lag, while its contemporaneous value and higher order lags were omitted. This does not imply that all cattle placed on feed in quarter t are marketed for slaughter in period t+1. Cattle feeding periods and fed marketings must be analyzed within a dynamic context. For example, light calves (500 lbs.) placed on feed near the end of quarter t may not reach finishing stage (1100 lbs.) until quarter t+3. On the other hand, cattle that are placed in feedlots at heavier weights in quarter t would be finished in shorter time periods, i.e., periods t+1 or t+2. The estimated difference equation coefficient (.648) accounts for these varying placement weights and feeding intervals, and taken conjunctively with the feeder placement slope coefficient (.323), cumulative patterns of marketings are given over time.

The cumulative marketings are given by the geometric adjustment formula:

$$\partial QFED_{t+j}/\partial PLAC_t = \hat{\beta}(1 + \lambda + \lambda^2 + \ldots.) \qquad (3.01)$$

where j = 1, 2, 3, ...

Its application to the fed marketing equation indicates that a 1000 head increase in placements in period t results in additional fed marketings of 756 head in period t+3.

The percentage fed supply responses to changes in corn price, by-product price and interest rate are given in Table 4. The magnitude of all percentage fed supply responses implies that fed cattle supply is relatively inelastic. The results show that for a 10% increase in corn price fed marketings decrease 0.4% in two quarters and 1.0% in the long run. A 10% increase in by-product value increases fed marketings 0.4% in two quarters and 1.1% in the long run. The fed supply response with respect to interest rate implies a 10% increase in interest rates decreases fed marketings by 0.1% in two quarters and 0.4% in the long run.

Cull Cow Sector

The final equation for cull cow price (Table 5) was estimated as a first order nonstochastic difference equation with an AR(1) error structure. The lagged expectation of the dependent variable was not highly significant and the coefficient value was relatively small, indicating a rapid geometric adjustment process in cull market price. The estimated coefficients on contemporaneous values of the independent variables nonfed slaughter (fed slaughter omitted because of statistical insignificance), by-product price, and personal income were significant at the 95% level; however, coefficients on lagged values were not statistically significant. The signs of the estimated coefficients indicate that increases in nonfed slaughter decrease cull cow price, increases in by-product value increase cull cow price, and income negatively impacts cow price. The two former findings agree with a priori reasoning; however, the sign of the income effect for cow beef agrees with previous studies that have shown negative impacts on lower quality beef.

Table 5. Statistical Results for the Quarterly Cull Cow Price and Supply Equations.[a]

		Variables[b]										
Equation	Constant	D2	D3	D4	$\hat{TOTNF}$[c]	BPV	Y	$\hat{PFEED}$	$\hat{PCOW}$	E(DEP-1)[d]	E(DEP-2)[e]	AR
PCOW	27.335	.487	.035	.088	-.002	3.125	-.020			.170		.402
	(4.081)	(1.269)	(.064)	(.153)	(-4.408)	(7.223)	(-3.817)			(1.358)		(3.371)
QCOW	-308.950	555.780	736.720	716.590				-55.656	85.275	1.593	-.653	.630
	(-2.778)	(4.180)	(7.831)	(7.648)				(-3.040)	(3.103)	(11.009)	(-4.789)	(6.181)

[a]The asymptotic t-ratios are given in parentheses under each coefficient. The critical boundary is 2.010 for a 95 percent probability level.

[b]Regression test statistics are defined as: $\bar{R}^2$ = adjusted R-squared, Sy = standard error of the estimate, and DW = Durbin-Watson statistic. The test statistics for each equation are: PCOW, $\bar{R}^2$ = .943, Sy = .989, DW = 1.978; QCOW, $\bar{R}^2$ = .888, Sy = 147.779, DW = 1.847.

[c]A ^ signifies that predicted values of the appropriate variable were substituted for observed values.

[d]E(DEP-1) = the lagged expectation of the appropriate dependent variable.

[e]E(DEP-2) = the second order lagged expectation of the appropriate dependent variable.

The responses of cull cow price to changes in corn price, by-product price, and interest rate are presented in Table 6. The largest response occurs from changes in by-product values. For example, a 10% increase in by-product price increases cull cow price by 5.1% in the short run and 5.8% in the long run; a 10% increase in corn price results in a 0.3% decline in cull cow price in both the short run and in the long run, while a 10% increase in interest rates decreases cull cow price 0.16% in the short run and 0.2% in the long run. Note in all cases that the majority of the adjustments in price responses occur within two quarters and that in one year cow price stabilizes, showing little difference from the long run. These results are attributed to the rapid geometric price adjustments inherent in the cull cow market as shown by the difference equation coefficient.

The quantity of cull cow marketings was estimated as a second order nonstochastic difference equation with an AR(1) error structure. Coefficients on lagged feeder price and lagged cull cow price were not statistically significant; thus, only their contemporaneous values were retained. The signs of the coefficients on both variables are consistent with the economic logic underlying supply behavior. That is, if there was an increase in feeder cattle price, producers would have an incentive to expand beef cow herds for capital consumption purposes, resulting in less cull cow slaughter. On the other hand, an increase in cull cow price would encourage additional cull cow slaughter so producers could meet current consumption requirements such as increased cash flow needs.

Table 6. Partial Derivatives and Percentage Price and Supply Responses in the Cull Cow Sector.[a]

	Quarters				
Equation	1	2	4	8	Long run
∂PCOW/∂PCORN	-.370 (-.027)	-.433 (-.032)	-.445 (-.033)	-.446 (-.033)	-.446 (-.033)
∂QCOW/∂PCORN	201.730 (.116)	523.090 (.301)	1299.100 (.747)	2603.300 (1.498)	3362.200 (1.934)
∂PCOW/∂BPV	3.363 (.508)	3.785 (.571)	3.869 (.584)	3.871 (.584)	3.871 (.584)
∂QCOW/∂BPV	50.228 (.060)	266.220 (.316)	577.450 (.684)	2225.700 (2.638)	3108.900 (3.684)
∂PCOW/∂INT	-.030 (-.016)	-.035 (-.019)	-.036 (-.020)	-.036 (-.020)	-.036 (-.020)
∂QCOW/∂INT	-.506 (-.002)	-1.310 (-.006)	-3.255 (-.014)	-6.523 (-.028)	-8.439 (-.036)

[a]The top figures are partial derivatives and the figures in parentheses are percentage responses (calculated at the mean values of the variables). These figures represent the cumulative effects over the indicated number of quarters.

The behavior of cow slaughter is characterized by the roots of the second order difference equation. In this case the roots are complex, indicating oscillating patterns in cull cow slaughter that stabilize after a market shock. The rate of dampening in the oscillation is given by the value of the second order difference equation coefficient, which equals -.653. Its relative size indicates that there is a rather lengthy adjustment process in the slaughter cow market. In fact, analysis of the distributed lag coefficients used to derive the long run response coefficients (Table 6) indicates that a permanent change in corn price produces a dampening cyclical pattern in cow slaughter that reaches an equilibrium in 32 to 40 quarters (not shown). This time period is equivalent to 8-10 years, nearly the length of the traditional cattle cycle.

The supply response coefficients for the cull cow slaughter model are reported in Table 6. Inspection of the results indicates that cull cow slaughter is increasingly responsive to changes in the exogenous variables as the number of adjustment periods increases. For example, a 10% increase in corn price increases the quantity of cull cows marketed by 1.2% in the short run and by 19.3% in the long run. Similarly, a 10% increase in by-product value increases cull cow marketings by 0.6% in the short run and 36.8% in the long run. The large long run responses to corn price and by-product price reflect the lengthy cyclical adjustments inherent in the cull cow market discussed above. The response of cull cow slaughter to changes in interest rate is quite inelastic, however. A 10% increase in interest rate decreases the quantity of cull cows marketed by 0.02% in the short run and only 0.36% in the long run.

Nonfed Cattle Sector

The price of nonfed steers (Select grade) is estimated as a first order nonstochastic difference equation with an AR(1) error structure (Table 7). The independent variables are the contemporaneous values of fed cattle slaughter, total nonfed cattle slaughter, and disposable income while both the contemporaneous value and a one period lag on

Table 7. Statistical Results for the Quarterly Nonfed Steer and Heifer Price and Supply and Total Nonfed Cattle Supply Equations.[a]

		Variables[b]													
Equa.	Constant	D2	D3	D4	$\widehat{QFED}$[c]	$\widehat{TOTNF}$	BPV	BPV-1	Y	$\widehat{PLAC}$	PLAC-1	PLAC-2	E(DEP-1)[d]	AR	MA
PGOOD	26.581	-.035	-.661	-.225	-.002	-.001	5.370	-3.331	-.010				.589	.218	
	(2.353)	(-.055)	(-1.050)	(-.326)	(-2.178)	(-2.533)	(7.568)	(-3.127)	(-1.756)				(3.312)	(1.713)	
QNFSH	1490.000	-478.260	-160.520	-65.597							-.449	.220	.935	.827	.362
	(7.118)	(-1.681)	(-1.425)	(-.669)							(-5.277)	(2.183)	(23.268)	(5.873)	(1.660)
TOTNF	1228.800	944.450	1257.800	1752.500						-.387			.965	.778	
	(3.624)	(8.717)	(11.400)	(11.815)						(-6.833)			(32.177)	(9.513)	

[a]The asymptotic t-ratios are given in parentheses under each coefficient. The critical boundary is 2.010 for a 95 percent probability level.

[b]Regression test statistics are defined as: $\bar{R}^2$ = adjusted R-squared, Sy = standard error of the estimate, and DW = Durbin-Watson statistic. The test statistics for each equation are: PGOOD, $\bar{R}^2$ = .913, Sy = 1.354, DW = 1.982; QNFSH, $\bar{R}^2$ = .894, Sy = 150.015, DW = 2.037; TOTNF, $\bar{R}^2$ = .914, Sy = 261.157, DW = 2.296.

[c]A ^ signifies that predicted values of the appropriate variable were substituted for observed values.

[d]E(DEP-1) = the lagged expectation of the appropriate dependent variable.

by-product price were included. The estimated coefficients for these independent variables were all significant at the 95% probability level.

The negative signs on the estimated coefficients for quantities of fed and nonfed cattle slaughtered are consistent with theoretical reasoning, i.e., increases in fed and nonfed slaughter would decrease Select price. The negative sign on the income coefficient may partly reflect the statistical problems discussed earlier in the case of Choice price; however, other empirical work has shown and justified negative income effects for lower grade beef (Ospina and Shumway, 1979).

The percentage price responses of Select price to corn price, by-product price, and interest rate are presented in Table 8. The largest response (though less than unity) is with respect to by-product price, while changes in the other two variables generate relatively small responses in Select price. For example, a 10% increase in by-product value increases nonfed steer price by 5.9% in the short run and 5.4% in the long run. A 10% increase in interest rate decreases nonfed steer price 0.05% in the short run and 0.1% in the long run, while a 10% increase in corn price decreases nonfed steer price by 0.1% in the short run and 0.2% in the long run.

The nonfed steer and heifer supply equation was estimated as a first order nonstochastic difference equation with an ARMA(1,1) error term (Table 7). The large value of the difference equation coefficient (.935) prompted testing the rational lag as a second order difference equation; however, the asymptotic t-ratio for the difference equation coefficient λ_2 was not statistically different from zero.

Table 8. Partial Derivatives and Percentage Price and Supply Responses in the Nonfed Cattle Sector.[a]

	Quarters				
Equation	1	2	4	8	Long run
∂PGOOD/∂PCORN	-.174	-.277	-.372	-.417	-.423
	(-.009)	(-.014)	(-.019)	(-.022)	(-.022)
∂QNFSH/∂PCORN	---	118.540	333.010	684.410	1823.700
	---	(.155)	(.437)	(.897)	(2.391)
∂PGOOD/∂BPV	5.482	5.307	5.144	5.067	5.057
	(.585)	(.567)	(.549)	(.541)	(.540)
∂QNFSH/∂BPV	---	-137.840	-319.180	-616.210	-1577.600
	---	(-.372)	(-.862)	(-1.664)	(-4.260)
∂PGOOD/∂INT	-.014	-.022	-.030	-.034	-.034
	(-.005)	(-.009)	(-.011)	(-.013)	(-.013)
∂QNFSH/∂INT	---	13.776	38.696	79.514	211.610
	---	(.134)	(.375)	(.771)	(2.051)
∂TOTNF/∂PCORN	176.180	348.660	682.830	1310.100	8292.300
	(.066)	(.131)	(.257)	(.493)	(3.121)
∂TOTNF/∂BPV	-113.250	-152.910	-229.770	-374.090	-1988.200
	(-.088)	(-.119)	(-.178)	(-.290)	(-.542)
∂TOTNF/∂INT	14.248	28.198	55.229	105.980	673.630
	(.040)	(.078)	(.154)	(.295)	(1.874)

[a]The top figures are partial derivatives and the figures in parentheses are percentage responses (calculated at the mean values of the variables). These figures represent the cumulative effects over the indicated number of quarters.

Nonfed steer and heifer slaughter is estimated as a function of second order distributed lags on placements of cattle on feed, PLAC-1 and PLAC-2, with the contemporaneous value omitted. These distributed lag effects represent resource trade-offs between the fed and nonfed sectors when economic conditions change. For example, if a bumper crop caused a decrease in corn price, there would likely be an increase in placements of cattle on feed (see placement equation, Table 1). For a relatively fixed supply of calves and yearlings, this results in more cattle allocated to grain finishing (due to increased finishing returns) and results in less cattle allocated to nonfed steer and heifer slaughter. The sum of the coefficients on PLAC-1 and PLAC-2 is negative, which is consistent with the trade-off behavior.

The nonfed steer and heifer supply response equation coefficients are reported in Table 8. Supply response with respect to all the exogenous variables appears to be quite elastic. This is particularly seen via the long run coefficients as: (1) a 10% increase in corn price increases nonfed steer and heifer marketings 23.9% over the long run, (2) a 10% increase in interest rates increases nonfed steer and heifer marketings by 20.5% in the long run, and (3) a 10% increase in by-product value decreases nonfed steer and heifer marketings by 42.6% in the long run. Again, the relative magnitude and direction of these impacts reflects the sensitive trade-off with the fed cattle industry, particularly since the number of nonfed steers and heifers slaughtered is based on economic incentives in cattle finishing rather than direct incentives in producing lower grade cattle.

Total nonfed cattle supply is an aggregation of nonfed steer and heifer marketings, cull cow marketings, and bull and stag marketings. Total nonfed supply is estimated as a first order nonstochastic difference equation with an AR(1) error structure (Table 7). Compared with the maintained hypothesis of equation (2.09), the contemporaneous and lagged variables of cull cow price and feeder cattle price were omitted due to lack of statistical significance of the respective estimated coefficients. Thus, the instrument variable for feeder cattle placements was the primary regressor. Its negative coefficient is consistent with the economic reasoning underlying the supply effects discussed earlier in the QNFSH equation.

As found with nonfed steer and heifer slaughter response, relatively large long run effects are associated with the total nonfed supply response coefficients (Table 8) because of the large difference equation coefficient (.965). For example, a 10% increase in interest rates increases total nonfed cattle supply by 18.7% in the long run, a 10% increase in by-product value decreases total supply of nonfed cattle by 15.4% in the long run, and a 10% increase in corn price increases total nonfed supplies by 31.2% in the long run. Note the corn price effect dominates due to the critical impact of the value of grain concentrates on the cattle finishing industry, hence, the trade-off implications for the total nonfed slaughter market and fed cattle market.

Simulated Cattle Industry Revenue Adjustments

Beef cattle industry gross revenue adjustments to simulated permanent changes in free market corn price and the government corn loan rate are presented and evaluated in the following section. Simulated impacts on revenues from shifts in corn prices are analyzed for the fed, nonfed, cow, and feeder cattle sectors as presented in Table 9. Changes in both sets of prices are based on two standard deviations from their sample means. The simulation procedure involves calculating cumulative revenue changes based on first order partial derivatives of prices and quantities up through five years and then long run estimates are provided.

Long run price and supply responses for the fed cattle and feeder cattle sectors (Tables 2 and 4) indicate prices and supplies; hence, returns in both sectors respond inversely to corn price changes. For an increase in free market corn price of two standard deviations ($.872/bu.), gross returns would decrease by $1,106,672 in the fed cattle sector and $58,619,473 in the feeder cattle sector in one year. By two years the respective decreases are $1,727,415 and $84,701,087. After a period of five years, gross revenue decreases by $1,879,063 in the fed cattle sector and $96,370,936 in the feeder cattle sector. Note the cattle market is essentially at an equilibrium state after 20 quarters; thus there is little difference between five year period and long run revenue estimates.

Table 9. Estimated Cattle Industry Revenue Changes Resulting from a Two Standard Deviation Increase in Corn Price.[a]

# of qtrs.	Fed Sector[b]	Nonfed Sector[c]	Cow Sector[d]	Feeder Sector[e]
1	---	---	715.958	-10831.825
2	-371.987	271.519	2172.569	-29073.349
4	-1106.672	1027.323	5545.131	-58619.473
6	-1571.846	1749.306	8692.106	-75501.116
8	-1727.415	2365.379	11137.001	-84701.087
10	-1812.098	2888.028	12811.850	-89823.741
12	-1853.472	3336.175	13832.161	-92755.211
16	-1876.474	4058.486	14607.768	-95444.197
20	-1879.063	4608.284	14632.580	-96370.936
LR	-1879.270	6396.529	14383.599	-96863.882

[a]The figures represent cumulative effects. All figures are in thousands of dollars. One standard deviation (STD DEV) of corn price is $.436/bu.

[b]Fed Sector = ∂PFED/∂PCORN x ∂QFED/∂PCORN x average live weight (ALW) of 10.5 cwt. x 2 STD DEV of corn price ($.872/bu.)

[c]Nonfed Sector = ∂PGOOD/∂PCORN x ∂QNFSH/∂PCORN x ALW of 9.5 cwt. x 2 STD DEV of corn price ($.872/bu)

[d]Cow Sector = ∂PCOW/∂PCORN x ∂QCOW/∂PCORN x ALW of 11.0 cwt. x 2 STD DEV of corn price ($.872/bu)

[e]Feeder Sector = ∂PFEED/∂PCORN x ∂PLAC/∂PCORN x ALW of 6.5 cwt. x 2 STD DEV of corn price ($.872/bu.)

The relationships between free market corn price and gross revenues in the cull cow and nonfed steer and heifer sectors are not as obvious since slaughter prices and slaughter marketings change in opposite directions. Cattle price responses with respect to changes in corn price for cows and nonfed steers and heifers over the long run are -.033 and -.022, respectively (Tables 6 and 8). Taken alone, these sector responses would indicate an inverse correlation between corn price and gross revenues. However, the long term supply response coefficients (with respect to corn price) are positive for both the quantities of cull cow marketings (1.934) and nonfed steer and heifer slaughter (2.391).

The net effects of the two responses indicate likely directional change in revenues. It can be inferred from the reduced form coefficients of the model that, subsequent to a shift in corn price, the percentage increases in nonfed supplies (cull cows and steers and heifers) outweigh the percentage decreases from their respective prices. Thus, gross revenues in the cull cow sector and the nonfed steer and heifer sector are positively correlated with changes in corn price. These results are presented in Table 9. In a one year period, a two standard deviation increase in corn price increases gross revenue by $1,027,323 in the nonfed steer and heifer sector and $5,545,131 in the cull cow sector, while the revenues increase to $4,608,284 and $14,632,580, respectively, over a period of five years.

Conceivably, the government loan rate for corn is important to beef revenue adjustments since the loan rate is effectively a floor to free market price. To examine the relationship between the loan rate and free market price for corn, a simple regression expressing free market corn price as a function of contemporaneous loan rate and an AR(1) error structure was estimated. Results of the estimation are:

$$PCORN = \underset{(2.855)}{.980} + \underset{(.511)}{.196}\ LOAN + \underset{(21.988)}{.943}\ AR \qquad (3.02)$$

The numbers in parentheses are the asymptotic t-ratios of the estimated coefficients, and the adjusted R-squared is .858; the standard error of the estimate is .164, and the Durbin-Watson statistic equals 2.075. The lack of statistical significance for the coefficient of the loan rate variable reflects the fact that the market price of corn rarely equaled or went below the loan rate during the 1973-1987 sample period. Thus, equation (3.02) suggests (for the data period studied) a very weak relationship between changes in the government loan rate and revenue changes in the beef cattle industry.

Cattle industry revenue adjustments resulting from a two standard deviation ($.30/bu.) change in the loan rate were, nevertheless, calculated and are presented in Table 10. The loan rate is arbitrarily decreased since, politically speaking, this would be the likely direction. Since the market price of corn is positively correlated with changes in the corn loan rate (albeit weak), the revenue adjustments in Table 10 are opposite in sign of those presented in Table 9. The adjustments are also smaller in magnitude because of a smaller standard deviation for the corn loan rate, and the fact that the partial derivative in equation (3.02) indicates a 10 cent per bushel change in the loan rate results in about a 2 cent per bushel change in free market price.

Table 10. Estimated Cattle Industry Revenue Changes Resulting from a Two Standard Deviation Decrease in Corn Loan Rate.[a]

# of qtrs.	Fed Sector[b]	Nonfed Sector[c]	Cow Sector[d]	Feeder Sector[e]
1	---	---	-48.277	730.403
2	25.084	-18.309	-146.499	1960.451
4	74.624	-69.274	-373.915	3952.781
6	105.992	-117.958	-586.119	5091.130
8	116.482	-159.500	-750.981	5711.495
10	122.192	-194.743	-863.918	6056.922
12	124.982	-224.962	-932.719	6254.595
16	126.533	-273.669	-985.019	6435.916
20	126.708	-310.742	-986.692	6498.407
LR	126.721	-431.326	-969.903	6531.647

[a]The figures represent cumulative effects. All figures are in thousands of dollars. One standard deviation (STD DEV) of corn loan rate is $.150/bu.

[b]Fed Sector = ∂PFED/∂PCORN x ∂QFED/∂PCORN x average live weight (ALW) of 10.5 cwt. x ∂PCORN/∂LOAN x 2 STD DEV of corn loan rate ($.300/bu.)

[c]Nonfed Sector = ∂PGOOD/∂PCORN x ∂QNFSH/∂PCORN x ALW of 9.5 cwt. x ∂PCORN/∂LOAN x 2 STD DEV of corn loan rate ($.300/bu)

[d]Cow Sector = ∂PCOW/∂PCORN x ∂QCOW/∂PCORN x ALW of 11.0 cwt. x ∂PCORN/∂LOAN x 2 STD DEV of corn loan rate ($.300/bu)

[e]Feeder Sector = ∂PFEED/∂PCORN x ∂PLAC/∂PCORN x ALW of 6.5 cwt. x ∂PCORN/∂LOAN x 2 STD DEV of corn loan rate ($.300/bu.)

The increases in fed cattle and feeder cattle prices and supplies in response to a decrease in corn loan rate are reflected in the gross revenues changes presented in Table 10. For example, gross revenues increase by $74,624 in the fed sector and $3,952,781 in the feeder sector in the first year, and increase to $116,482 and $5,711,495, respectively, by the second year; by five years the respective gross revenues cumulatively increase to $126,708 and $6,498,407.

Gross revenues in the cull cow sector and the nonfed steer and heifer sector decrease in response to the loan rate change. The decrease occurs even though there were increases in cull cow price and Select price. These results parallel the reasoning given earlier; that is, subsequent to a loan rate decrease, the percentage reduction in the quantity of cows and nonfed steers and heifers marketed is larger than the percentage increase in prices, resulting in declining gross revenues for both nonfed sectors. A two standard deviation ($.30/bu.) decrease in the corn loan rate decreases gross revenue by $69,274 in the nonfed steer and heifer sector and $373,915 in the cow sector after one year. After five years gross revenues in the nonfed steer and heifer and cull cow sectors decrease, respectively, by $310,742 and $986,692.

CHAPTER 4

SUMMARY AND CONCLUSIONS

The purpose of this study was to estimate the impacts of changes in exogenous factors, particularly feed price, on U.S. fed and nonfed cattle prices and supplies over time. A quarterly econometric model representing the structural and behavioral characteristics of the U.S. beef cattle industry was specified and statistically estimated. The beef model functions were estimated within a rational distributed lag framework characterized by nonstochastic difference equations and ARMA error structures. Coefficients derived from the reduced form of the estimated model were used to calculate percentage price and supply responses which were in turn used to estimate short and long run adjustments in cattle prices and marketings.

Adjustments in cattle prices and quantities resulting from exogenous shifts in free market corn price and corn loan rate were used to simulate adjustments in gross revenues in the feeder, fed, cull cow, and nonfed steer and heifer cattle sectors. An evaluation of the model results follows. Conclusions and limitations of the research are presented at the end of the chapter.

Feeder cattle sector equations were specified and estimated for feeder price and feeder cattle placements. Both equations were estimated as first order nonstochastic difference equations and included seasonal binary variables. Feeder price was regressed on contemporaneous values of corn price, placements, and fed price. The positive sign on the estimated coefficient of the placement variable reflects the jointly dependent relationship between feeder price and placements, i.e., increasing placement demand is manifested by increased feeder price.

Regressors in the feeder placement equation included contemporaneous corn price, fed cattle price, feeder cattle price, and interest rate. Percentage responses with respect to corn price, by-product price, and interest rate changes were similarly inelastic for both feeder price and placements. Corn price change elicited the greatest long run response from both variables with a percentage feeder price response of -.393 and a percentage placement response of -.409.

The price of fed cattle was estimated as a first order nonstochastic difference equation with seasonal binary variables and contemporaneous values of the independent variables fed slaughter supply, total nonfed cattle slaughter supply, personal disposable income, and by-product price. A one quarter lag on by-product value was also included. All of the estimated coefficients had the expected signs with the exception of the coefficient on income which had a negative sign. The negative income coefficient may be a result of sample characteristics of the data since there was a negative trend between real fed price and real disposable income.

The fed supply equation was estimated as a first order nonstochastic difference equation. Feeder cattle placement was the main independent variable with seasonal binaries included. The adjusted R-squared was less than desirable at .628. The coefficient for a one period lag on placements was statistically significant while the contemporaneous value and higher order lags were omitted. However, cattle placed on feed in period t are not all marketed in period t+1 because of different placement weights. Cumulative patterns of marketings are accounted for by the fed marketing difference equation coefficient acting in conjunction with the lagged feeder placement slope coefficient.

Fed price and supply percentage responses were inelastic (less than unity) with respect to changes in corn price, interest rates, and by-product value. The largest long run responses for fed price and supply are associated with by-product value: .596 for fed price and .106 for fed supply. The dominant influence of by-product price to some extent reflects the importance to packers of returns generated from by-product sales.

Cull cow price was estimated as a first order nonstochastic difference equation with seasonal binary variables; however, the lagged expectation of the dependent variable was not highly significant and the coefficient value was relatively small. The small coefficient results in a rapid geometric price adjustment in the cull cow market. Contemporaneous values of total nonfed slaughter, by-product value, and personal disposable income were found to be important explanatory variables. A negative income effect for cull cow beef is implied by the estimated negative coefficient on the income variable. Previous studies have reported both positive and negative signs for the income coefficient. By-product value has the largest percentage effect on cull cow price at .508 in the short run and .584 in the long run.

Quantity of cull cow marketings was estimated as a second order nonstochastic difference equation. Seasonal binaries, the contemporaneous price of feeder cattle, and contemporaneous price of cull cows were the independent variables. The second order difference equation was characterized by complex roots, resulting in oscillating patterns in cull cow slaughter subsequent to a market shock. The adjustment time to equilibrium takes about 8-10 years, which is relatively close to the length of the traditional cattle cycle.

The nonfed cattle sector was described by estimating equations for the price of nonfed steers (Select grade), nonfed steer and heifer slaughter, and total nonfed cattle supply. All equations included seasonal binary variables and were estimated as first order nonstochastic difference equations.

Contemporaneous values of fed marketings, total nonfed marketings, personal disposable income, and by-product value (including a one quarter lag on by-product value) were the independent variables in the nonfed steer price equation. The coefficient on the income variable carried a negative sign which may reflect the negative trend between real beef price and real income discussed earlier. Other empirical studies have, however, rationalized negative income effects for lower grade beef (Ospina and Shumway, 1979). By-product value generated the largest long run percentage price response (.540) while corn and interest rate price responses were substantially smaller (-.022 and -.013, respectively).

Nonfed steer and heifer slaughter was a first order nonstochastic difference equation estimated as a function of first and second order lags on placements of cattle on feed. The percentage supply response coefficients were quite elastic, particularly with respect to by-product value, demonstrating a long run effect of -4.260. The sensitive trade-off effect between the fed and nonfed sectors resulting from economic incentives in producing Choice versus lower grade beef is the primary reason for the large supply responses.

Total nonfed cattle supply represents an aggregation of nonfed steer and heifer marketings, cull cow marketings, and bull and stag marketings. The primary regressor in the function was contemporaneous feeder cattle placements. It had a negative coefficient which was consistent with the effects discussed in the nonfed steer and heifer slaughter equation; that is, an increase in placements implies a smaller proportion of feeder cattle will enter the nonfed sector. The percentage supply responses are elastic, similar to those of nonfed steer and heifer slaughter. Corn price, because of its critical influence in the cattle finishing industry, has the largest impact with a long run supply response coefficient of 3.121.

Cattle industry revenue adjustments to exogenous changes in free market corn price and government loan rates were simulated. Cumulative gross revenues for the fed, nonfed, feeder, and cull cow sectors were calculated based on sequential first order partial derivatives of prices and marketings.

A two standard deviation increase in free market corn price decreased prices and supplies, and hence returns in the fed cattle and feeder cattle sectors by $1,879,063 and $96,370,936, respectively, over five years. Cattle prices in the cow sector and nonfed steer and heifer sector decreased in response to a corn price increase. However, gross revenues in the cull cow sector and nonfed steer and heifer sector are positively correlated with changes in corn price. Over a period of five years, a two standard deviation increase in corn price increases cow sector gross revenue by $14,632,580 and nonfed steer and heifer sector gross revenue by $4,608,284.

Conceptually, the government loan rate for corn is important to beef revenue adjustments since the loan rate effectively establishes a floor on free market corn price. In a simple regression, free market corn price was estimated as a function of the government loan rate in order to measure the loan rate's expected impact on industry revenues. However, the statistical results of the estimation were less than satisfactory, yet there is some degree of positive correlation between the two price series. In light of political pressure to reduce grain loan rates, the loan rate was arbitrarily decreased by two standard deviations. As a result of decreasing (instead of increasing) the corn loan rate, the cattle revenue adjustments in the loan rate analysis have the opposite sign of those in the free market price analysis. The adjustments are smaller because of a smaller standard deviation of corn loan rate and the weak relationship between market corn price and loan rate.

Fed cattle and feeder cattle prices and supplies increase in response to a two standard deviation decrease in corn loan rate. In particular, fed sector and feeder sector gross revenues increase by $126,708 and $6,498,407, respectively, over five years.

Gross revenues in the cull cow sector and the nonfed steer and heifer sector decrease in response to the loan rate changes. Cull cow price and Select price increase but they are more than offset by supply response decreases. Over a period of five years, cumulative revenues decrease in the cull cow sector by $986,692 and in the nonfed steer and heifer sector by $310,742. It should be noted, however, that increasing or decreasing gross revenues does not necessarily translate into increases or decreases in profits in these sectors since costs have not been measured.

This research has attempted to model the dynamic structural and behavioral characteristics of the U.S. beef cattle industry and properly measure intertemporal market effects. A more recent sample period and rational lag specification no doubt contributed to corn price effects that differ from empirical results of some other studies. With the exception of income, the current statistical results appear consistent with the economics of resource allocation between fed and nonfed cattle production. An important limitation of the study, and one which requires further research, is estimating market responses for second round effects. For example, analyzing the dynamic time paths of prices and marketings resulting from a permanent change in corn price did not account for changing beef cow herd supplies, nor was the production response of corn producers to a change in price taken into account. Thus, cheaper corn price could be a boost to feeder demand and price, but the long term result could entail expanded beef cow herds and larger feeder and stocker cattle supplies. On the other hand, lower corn loan rates (and possibly lower market price) could initiate a production response (acreage and yield) which would have long term implications for free market corn price. Thus, a more comprehensive model incorporating primary supply response and endogenous aspects of corn price could add to the marketing and price analysis of this study.

Another limitation stems from the structural changes that continue to occur in the cattle industry. Over the last 10 years the industry has steadily moved toward larger cattle finishing operations and larger meat packing and processing operations with more vertical integration. This model may not fully reflect the implications of these changes. In particular, the long run projections made in this study could be altered by the different institutional arrangements and price discovery taking place as a result of the structural changes in the U.S. cattle industry.

REFERENCES CITED

REFERENCES CITED

Arzac, Enrique R., and Maurice Wilkinson. "A Quarterly Econometric Model of United States Livestock and Feed Grain Markets and Some of Its Policy Implications." American Journal of Agricultural Economics 61, no. 2 (May 1979): 297-308.

Brester, G.W., and J.M. Marsh. "A Statistical Model of the Primary and Derived Market Levels in the U.S. Beef Industry." Western Journal of Agricultural Economics 8, no. 1 (1983): 34-49.

Buccola, S.T. "An Approach to the Analysis of Feeder Cattle Price Differentials." Southern Journal of Agricultural Economics 11 (July 1979): 61-65.

Burt, Oscar R. Estimation of Distributed Lags as Nonstochastic Difference Equations. Staff Paper No. 80-1, Department of Agricultural Economics and Economics, Montana State University, Bozeman, October 1978.

Burt, Oscar R., Stewart Townsend, and Jeffrey LaFrance. Instruction Manual for DYNREG: A Nonlinear Least Squares Algorithm for Distributed Lag Models and/or Regression Models with Time Series Error Terms. Staff Paper No. 86-4, Department of Agricultural Economics and Economics, Montana State University, Bozeman, August 1986.

Folwell, Raymond J., and Hosein Shapouri. An Econometric Analysis of the U.S. Beef Sector. Technical Bulletin No. 89, Washington State University, Pullman, 1977.

Freebairn, J.W., and G.C. Rausser. "Effects of Changes in the Level of U.S. Beef Imports." American Journal of Agricultural Economics 57 (1975): 81-84.

Griliches, Z. "Distributed Lags: A Survey." Econometrica 35 (1967): 16-46.

Hanssens, D.M., and Lon-Mu Liu. "Lag Specification in Rational Distributed Lag Structural Models." Journal of Business, Economics and Statistics 1 (October 1983): 316-325.

Johnston, J. Econometric Methods. 3rd ed. Oakland, CA: McGraw-Hill Book Co., 1984.

Jorgenson, D.W. "Rational Distributed Lag Functions." Econometrica 32 (1966): 135-149.

Kmenta, J. Elements of Econometrics. 2nd ed. New York: Mcmillan Publishing Co., 1986.

Kulshreshtha, S.B., and A.G. Wilson. "An Open Econometric Model of the Canadian Beef Cattle Sector." American Journal of Agricultural Economics 54 (1972): 84-91.

Langemeir, L., and R.G. Thompson. "Demand, Supply, and Price Relationships for the Beef Sector, Post World War II Period." American Journal of Agricultural Economics 49 (1967): 169-183.

Marsh, J.M. "A Rational Distributed Lag Model of Quarterly Live Cattle Prices." American Journal of Agricultural Economics 65 (August 1983): 539-547.

Marsh, J.M. "Estimating Slaughter Supply Response for U.S. Cattle and Hogs." North Central Journal of Agricultural Economics 6, no. 2 (July 1984): 18-28.

McCoy, J.H., and M.E. Sarhan. Livestock and Meat Marketing. 3rd ed. New York: Van Nostrand Reinhold Company., 1988.

Nelson, Glenn, and Thomas Spreen. "Monthly Steer and Heifer Supply." American Journal of Agricultural Economics 60, no. 1 (February, 1978): 117-125.

Ospina, Enrique, and R.C. Shumway. "Disaggregated Analysis of Short-Run Beef Supply Response." Western Journal of Agricultural Economics 4 (1979): 43-59.

Ospina, Enrique, and R.C. Shumway. Feed Grain Prices and Slaughter Beef Composition. Technical Report No. 81-1, Texas Agricultural Experiment Station, Texas A&M University, College Station, 1981.

Reutlinger, Schlomo. "Short Run Beef Supply Response." American Journal of Agricultural Economics 48 (1966): 909-919.

Rucker, R.R., O.R. Burt, and J.T. LaFrance. "An Econometric Model of Cattle Inventories." American Journal of Agricultural Economics 66 (1984): 131-144.

Shonkwiler, J.S., and Suzanne Hinckley. "A Generalized Supply Response/Factor Demand Model and Its Application to the Feeder Cattle Market." Western Journal of Agricultural Economics 10, no. 2 (December 1985): 245-253.

Shuib, A.B., and D.J. Menkhaus. "An Econometric Analysis of the Beef-Feed Grain Economy." Western Journal of Agricultural Economics 1 (1977): 152-156.

Tomek, W.G., and K.L. Robinson. Agricultural Product Prices. 2nd ed. Ithaca, NY: Cornell University Press, 1981.

Tryfos, P. "Canadian Supply Functions of Livestock and Meat." American Journal of Agricultural Economics 56 (1974): 107-113.

Ward, Clement E. Structure-Prices and Structure-Margins Relationships in the Beefpacking Industry. Paper No. A.E. 80125, Department of Agricultural Economics, Oklahoma State University, Stillwater, December 1980.

APPENDICES

APPENDIX A

ORIGINAL DATA

Table 11. Original Data.

Year	Qtr	LOAN	PCORN	QHOGS	QCHIX	QTURK	PCOWS	CPI	INT	PFEED	PFED	PLAC	QFED	QNONFED	QCOW	QBS	Y	PGOOD	BPV
		<-- Variables																	--->
1973	1	1.050	1.510	67.420	1903.000	169.100	30.670	1.287	7.360	50.770	43.280	5506.000	6779.000	137.000	1590.000	156.000	866.600	40.240	4.322
	2	1.050	1.870	69.930	2048.000	305.800	33.650	1.315	7.640	53.740	45.840	5248.000	6472.000	85.000	1434.000	164.000	891.700	43.280	4.665
	3	1.050	2.470	56.240	2048.000	682.900	35.430	1.344	8.080	57.980	48.570	4782.000	6137.000	145.000	1533.000	182.000	914.100	45.870	4.925
	4	1.050	2.410	67.390	2025.000	775.400	31.510	1.376	8.900	50.200	40.470	6436.000	6669.000	340.000	1690.000	174.000	939.900	38.660	4.518
1974	1	1.100	2.810	67.160	2008.000	226.000	31.950	1.414	9.180	47.780	45.460	4785.000	6171.000	486.000	1687.000	163.000	948.400	42.780	4.518
	2	1.100	2.560	70.050	2160.000	369.600	28.190	1.454	9.270	39.800	40.010	3656.000	6458.000	787.000	1391.000	181.000	969.500	36.730	3.744
	3	1.100	3.400	65.680	2109.000	701.600	23.780	1.499	9.470	34.640	43.910	4148.000	5703.000	1504.000	1914.000	242.000	998.000	39.530	3.743
	4	1.100	3.480	69.640	1849.000	624.100	18.320	1.542	9.800	29.310	38.190	5103.000	5705.000	1665.000	2519.000	232.000	1015.800	35.780	3.102
1975	1	1.100	2.870	62.530	1870.000	174.600	18.150	1.570	9.890	27.390	35.720	3962.000	5672.000	1630.000	2223.000	208.000	1025.400	32.480	2.691
	2	1.100	2.830	59.360	2103.000	303.600	22.850	1.595	9.320	34.670	48.030	4687.000	5175.000	1682.000	2420.000	273.000	1092.200	42.920	3.485
	3	1.100	3.000	51.020	2121.000	657.500	21.910	1.629	8.660	35.540	48.640	5205.000	5170.000	1933.000	3120.000	316.000	1095.700	41.320	3.881
	4	1.100	2.620	56.040	2032.000	667.500	21.460	1.655	8.560	38.060	46.050	6895.000	5099.000	1899.000	3188.000	305.000	1124.100	41.080	3.883
1976	1	1.500	2.600	58.100	2136.000	217.800	25.540	1.671	8.590	39.190	38.710	4593.000	6535.000	1389.000	2750.000	239.000	1152.500	35.890	3.892
	2	1.500	2.730	56.070	2334.000	388.700	29.480	1.692	8.490	48.890	41.420	4758.000	6119.000	1463.000	2331.000	257.000	1170.600	38.640	4.408
	3	1.500	2.700	59.940	2392.000	750.100	22.600	1.719	8.250	38.100	37.300	4886.000	6386.000	1650.000	2615.000	258.000	1192.800	33.840	4.466
	4	1.500	2.280	71.830	2205.000	701.900	21.640	1.738	8.120	36.400	39.000	7283.000	5855.000	1645.000	2925.000	236.000	1221.500	35.110	4.016
1977	1	2.000	2.370	65.900	2201.000	223.600	24.500	1.769	8.050	37.770	37.880	4757.000	6656.000	1065.000	2536.000	209.000	1250.100	34.630	4.553
	2	2.000	2.200	62.470	2447.000	390.500	26.610	1.805	7.920	41.100	40.770	4944.000	6331.000	1472.000	2164.000	226.000	1286.000	37.290	4.762
	3	2.000	1.740	60.980	2474.000	718.900	25.580	1.833	7.820	41.160	40.470	5579.000	6344.000	1640.000	2401.000	224.000	1323.200	36.500	4.312
	4	2.000	1.950	68.320	2296.000	690.200	24.570	1.853	7.930	40.700	42.420	8124.000	6268.000	1308.000	2771.000	221.000	1361.200	38.390	4.455
1978	1	2.000	2.060	64.680	2385.000	240.800	30.120	1.885	8.280	47.890	45.770	5321.000	6984.000	723.000	2319.000	183.000	1398.000	41.600	4.795
	2	2.000	2.310	63.470	2610.000	422.000	37.920	1.934	8.640	58.000	55.030	5470.000	6820.000	698.000	2146.000	212.000	1440.700	50.070	5.268
	3	2.000	2.020	61.840	2630.000	719.100	38.560	1.979	8.880	62.710	53.750	6416.000	6719.000	825.000	1993.000	206.000	1482.100	49.560	6.072
	4	2.000	2.060	67.720	2503.000	716.000	40.540	2.019	9.150	66.520	54.760	7212.000	6942.000	572.000	2013.000	197.000	1531.000	50.680	6.442
1979	1	2.100	2.140	66.800	2623.000	299.100	50.360	2.069	9.890	80.930	65.420	4782.000	6949.000	235.000	1565.000	148.000	1580.200	61.220	7.571
	2	2.100	2.420	72.470	2922.000	500.100	54.370	2.141	10.570	86.830	72.510	5070.000	6330.000	197.000	1370.000	147.000	1612.800	68.190	9.023
	3	2.100	2.500	73.610	2934.000	773.900	48.590	2.212	10.790	82.380	65.880	5151.000	6155.000	589.000	1340.000	164.000	1663.800	60.360	7.608
	4	2.100	2.350	84.120	2739.000	779.000	47.060	2.272	11.000	82.180	67.180	6762.000	5929.000	736.000	1656.000	168.000	1710.100	62.430	6.849
1980	1	2.250	2.270	80.790	2777.000	394.500	49.320	2.366	12.070	80.440	66.880	4334.000	6431.000	101.000	1450.000	163.000	1766.900	62.430	5.903
	2	2.250	2.420	83.470	3015.000	550.700	44.190	2.452	13.650	70.430	64.650	4717.000	5795.000	849.000	1375.000	174.000	1781.000	60.120	4.835
	3	2.250	2.930	73.860	2810.000	741.600	45.140	2.498	13.250	75.770	70.820	5567.000	5902.000	905.000	1608.000	201.000	1845.500	64.250	5.995
	4	2.250	3.270	82.130	2751.000	744.800	44.250	2.562	11.990	74.260	65.510	6134.000	5948.000	818.000	1900.000	187.000	1902.900	61.860	6.153
1981	1	2.400	3.210	78.930	2871.000	408.700	42.790	2.629	12.900	70.590	61.990	4378.000	6279.000	558.000	1577.000	172.000	1967.600	58.940	5.581
	2	2.400	3.220	75.310	3116.000	568.100	43.070	2.690	14.190	66.620	66.680	5093.000	5778.000	991.000	1526.000	200.000	2010.400	61.560	5.680
	3	2.400	2.820	70.930	3101.000	806.600	43.520	2.767	15.040	65.040	66.530	5054.000	6170.000	831.000	1660.000	218.000	2092.000	61.830	5.523
	4	2.400	2.400	80.080	2897.000	793.400	38.320	2.807	15.710	62.720	60.170	5907.000	5757.000	1175.000	1881.000	186.000	2120.500	57.030	5.217
1982	1	2.550	2.470	72.380	2918.000	420.600	38.050	2.830	15.260	63.050	63.360	5233.000	6151.000	617.000	1738.000	173.000	2207.200	58.210	5.156
	2	2.550	2.640	69.040	3144.000	541.500	42.460	2.873	14.840	66.480	70.460	5372.000	5886.000	857.000	1685.000	214.000	2241.800	65.590	5.371
	3	2.550	2.330	63.130	3162.000	780.500	42.220	2.928	14.420	66.530	64.190	5592.000	6253.000	679.000	1787.000	225.000	2278.600	60.000	5.196
	4	2.550	2.280	69.420	2943.000	779.200	37.090	2.934	13.800	63.230	58.870	6855.000	6073.000	885.000	2144.000	206.000	2318.100	54.210	4.734

Table 11--continued.

		Variables																	
Year	Qtr	LOAN	PCORN	QHOGS	QCHIX	QTURK	PCOWS	CPI	INT	PFEED	PFED	PLAC	QFED	QNONFED	QCOW	QBS	Y	PGOOD	BPV
1983	1	2.650	3.620	67.370	3062.000	477.400	40.080	2.932	12.830	67.280	61.520	4596.000	6434.000	408.000	1701.000	189.000	2345.500	55.740	4.805
	2	2.650	3.100	72.220	3276.000	600.700	42.760	2.969	11.770	66.920	67.040	5436.000	6246.000	702.000	1694.000	209.000	2387.700	60.900	5.543
	3	2.650	3.300	71.240	3138.000	786.000	39.510	3.004	11.370	59.010	60.890	5288.000	6657.000	764.000	1907.000	220.000	2447.900	56.040	5.952
	4	2.650	3.210	81.110	2924.000	784.800	35.050	3.030	11.820	61.620	60.610	6879.000	6143.000	890.000	2294.000	191.000	2520.400	55.630	5.976
1984	1	2.550	3.130	72.690	3093.000	451.000	38.990	3.063	12.050	66.310	67.580	5146.000	6457.000	468.000	2080.000	164.000	2612.700	60.760	6.285
	2	2.550	3.350	70.410	3357.000	615.000	42.400	3.097	12.100	65.300	66.010	4980.000	6351.000	785.000	1998.000	209.000	2646.300	59.680	6.886
	3	2.550	3.090	64.990	3344.000	810.700	40.510	3.130	12.610	63.940	64.280	5984.000	6423.000	753.000	2170.000	217.000	2693.800	58.110	6.726
	4	2.550	2.620	75.810	3223.000	808.100	37.330	3.153	13.100	65.590	63.490	7175.000	6240.000	696.000	2373.000	198.000	2729.600	58.030	5.989
1985	1	2.550	2.630	69.570	3272.000	506.100	41.680	3.174	12.910	68.300	62.240	4942.000	6675.000	211.000	1879.000	171.000	2762.200	57.070	5.428
	2	2.550	2.700	71.150	3562.000	660.000	41.220	3.236	12.500	67.010	57.660	4769.000	6539.000	664.000	1629.000	195.000	2848.400	53.820	5.685
	3	2.550	2.450	68.520	3535.000	898.400	36.000	3.212	12.160	60.840	52.160	5236.000	6745.000	720.000	1691.000	197.000	2847.200	46.920	5.869
	4	2.550	2.300	72.400	3391.000	877.600	34.390	3.265	12.030	62.070	42.080	7041.000	5869.000	721.000	2190.000	197.000	2906.600	55.310	6.232
1986	1	1.920	2.320	67.930	3414.000	556.000	36.850	3.273	11.400	62.600	57.220	4954.000	6512.000	323.000	1885.000	165.000	2966.000	52.550	5.898
	2	1.920	2.260	67.720	3673.000	717.000	37.540	3.265	11.250	59.740	54.520	4846.000	6578.000	806.000	2006.000	181.000	3022.400	48.520	6.289
	3	1.920	1.680	61.910	3620.000	938.000	38.120	3.289	11.250	64.080	58.910	6103.000	6640.000	881.000	1941.000	191.000	3038.200	52.160	6.221
	4	1.920	1.500	67.770	3558.000	921.000	36.370	3.308	11.000	64.740	60.310	6444.000	6097.000	777.000	2128.000	177.000	3061.600	54.940	6.170
1987	1	1.820	1.430	66.460	3732.000	668.000	42.360	3.345	10.100	70.500	60.460	5309.000	6494.000	456.000	1652.000	163.000	3125.900	54.840	6.583
	2	1.820	1.700	63.000	3910.000	867.000	44.440	3.389	10.000	73.430	68.600	5478.000	6349.000	747.000	1602.000	180.000	3130.600	61.080	7.761
	3	1.820	1.520	64.640	3966.000	109.900	46.540	3.426	10.000	79.030	65.040	6348.000	6805.000	600.000	1636.000	182.000	3195.300	58.660	7.762
	4	1.820	1.670	76.200	3891.000	108.100	45.980	3.456	10.700	78.470	64.310	6360.000	6309.000	588.000	1717.000	167.000	3272.600	59.550	7.733

APPENDIX B

INSTRUMENT VARIABLE EQUATIONS AND PREDICTED VALUES

Instrument Variable Equations

$$\widehat{PFEED} = \underset{(.020)}{.491}\ CONSTANT - \underset{(-1.045)}{1.685}\ D2 - \underset{(-1.908)}{2.609}\ D3 - \underset{(-1.577)}{1.853}\ D4 - \underset{(-.216)}{.112}\ INT_t$$

$$+ \underset{(.471)}{.260}\ INT_{t-1} - \underset{(-.830)}{1.572}\ PCORN_t - \underset{(-1.625)}{3.505}\ PCORN_{t-1} + \underset{(4.317)}{5.884}\ BPV_t$$

$$- \underset{(-1.362)}{2.234}\ BPV_{t-1} + \underset{(.975)}{.032}\ Y_t - \underset{(-1.327)}{.040}\ Y_{t-1} + \underset{(.416)}{.001}\ QCOW_{t-1}$$

$$+ \underset{(.584)}{.310}\ PGOOD_{t-1} + \underset{(1.517)}{.632}\ PCOW_{t-1} + \underset{(.694)}{.219}\ PFED_{t-1}$$

$$- \underset{(-.200)}{.144E\text{-}03}\ PLAC_{t-1} + \underset{(.578)}{.001}\ QFED_{t-1} - \underset{(-.249)}{.001}\ QNFSH_{t-1}$$

$\bar{R}^2 = .926$ Sy = 1.759 DW = 2.156

$$\widehat{PLAC} = \underset{(1.957)}{11603.000}\ CONSTANT + \underset{(.689)}{151.210}\ D2 + \underset{(4.074)}{989.090}\ D3 + \underset{(9.913)}{2154.700}\ D4$$

$$- \underset{(-.041)}{5.096}\ INT_t - \underset{(-.086)}{11.238}\ INT_{t-1} - \underset{(-2.191)}{1007.200}\ PCORN_t$$

$$- \underset{(-.226)}{104.700}\ PCORN_{t-1} + \underset{(1.945)}{631.130}\ BPV_t - \underset{(-.590)}{229.770}\ BPV_{t-1} - \underset{(-.045)}{.345}\ Y_t$$

$$- \underset{(-.753)}{5.297}\ Y_{t-1} + \underset{(1.373)}{.431}\ QCOW_{t-1} + \underset{(.390)}{29.284}\ PFED_{t-1} - \underset{(-.971)}{159.870}\ PCOW_{t-1}$$

$$+ \underset{(.794)}{58.379}\ PFEED_{t-1} - \underset{(-.206)}{.090}\ QFED_{t-1} - \underset{(-.527)}{67.114}\ PGOOD_{t-1}$$

$$- \underset{(-1.338)}{.714}\ QNFSH_{t-1}$$

$\bar{R}^2 = .799$ Sy = 417.369 DW = 2.142

$$\widehat{PFED} = \underset{(.485)}{12.692\ CONSTANT} + \underset{(.249)}{.422\ D2} - \underset{(-.625)}{.950\ D3} - \underset{(-.876)}{1.073\ D4} + \underset{(.725)}{.401\ INT_t}$$

$$- \underset{(-.432)}{.252\ INT_{t-1}} + \underset{(1.282)}{2.619\ PCORN_t} - \underset{(-1.503)}{3.428\ PCORN_{t-1}} + \underset{(3.560)}{5.158\ BPV_t}$$

$$- \underset{(-.954)}{1.631\ BPV_{t-1}} - \underset{(-.011)}{.363E{-}03\ Y_t} - \underset{(-.417)}{.013\ Y_{t-1}} - \underset{(-1.655)}{.003\ QCOW_{t-1}}$$

$$+ \underset{(2.574)}{.946\ PGOOD_{t-1}} - \underset{(-.605)}{.445\ PCOW_{t-1}} - \underset{(-.287)}{.094\ PFEED_{t-1}}$$

$$+ \underset{(.012)}{.925E{-}05\ PLAC_{t-1}} + \underset{(.458)}{.001\ QFED_{t-1}} + \underset{(.537)}{.001\ QNFSH_{t-1}}$$

$\bar{R}^2 = .861$ $\qquad$ $Sy = 1.858$ $\qquad$ $DW = 2.038$

$$\widehat{QFED} = \underset{(1.347)}{3271.500\ CONSTANT} + \underset{(1.166)}{287.920\ D2} + \underset{(1.590)}{351.950\ D3} - \underset{(-.257)}{45.144\ D4}$$

$$- \underset{(-.471)}{37.081\ INT_t} - \underset{(-.253)}{20.566\ INT_{t-1}} - \underset{(-1.630)}{471.080\ PCORN_t}$$

$$+ \underset{(1.879)}{612.810\ PCORN_{t-1}} - \underset{(-.830)}{154.520\ BPV_t} - \underset{(-.620)}{153.890\ BPV_{t-1}} + \underset{(1.397)}{6.651\ Y_t}$$

$$- \underset{(-1.224)}{5.477\ Y_{t-1}} + \underset{(1.344)}{.285\ QCOW_{t-1}} + \underset{(.068)}{3.201\ PFED_{t-1}} + \underset{(2.057)}{191.570\ PCOW_{t-1}}$$

$$- \underset{(-.494)}{21.122\ PFEED_{t-1}} + \underset{(3.298)}{.359\ PLAC_{t-1}} - \underset{(-1.433)}{90.086\ PGOOD_{t-1}}$$

$$- \underset{(-.623)}{.166\ QNFSH_{t-1}}$$

$\bar{R}^2 = .600$ $\qquad$ $Sy = 266.245$ $\qquad$ $DW = 2.303$

$$\widehat{PCOW} = -\ 4.719\ CONSTANT + .284\ D2 - .669\ D3 - 1.311\ D4 + .113\ INT_t$$
$$(-.369) \qquad (.345) \qquad (-.932) \qquad (-2.180) \qquad (.430)$$

$$-\ .028\ INT_{t-1} - .795\ PCORN_t - .525\ PCORN_{t-1} + 3.331\ BPV_t$$
$$(-.100) \qquad (-.822) \qquad (-.483) \qquad (4.800)$$

$$-\ 1.605\ BPV_{t-1} + .016\ Y_t - .024\ Y_{t-1} - .001\ QCOW_{t-1}$$
$$(-1.996) \qquad (.975) \qquad (-1.565) \qquad (-1.107)$$

$$+\ .214\ PGOOD_{t-1} + .188\ PFEED_{t-1} + .145\ PFED_{t-1} + .001\ PLAC_{t-1}$$
$$(.843) \qquad (2.003) \qquad (.909) \qquad (1.483)$$

$$+\ .001\ QFED_{t-1} - .001\ QNFSH_t$$
$$(1.708) \qquad (-.069)$$

$\bar{R}^2 = .953$ $\qquad$ Sy = .890 $\qquad$ DW = 2.527

$$\widehat{TOTNF} = 6737.500\ CONSTANT + 337.270\ D2 + 560.350\ D3 + 741.290\ D4$$
$$(2.668) \qquad (1.679) \qquad (2.906) \qquad (4.720)$$

$$+\ 14.050\ INT_t - 47.300\ INT_{t-1} + 434.700\ PCORN_t$$
$$(.204) \qquad (-.653) \qquad (1.719)$$

$$-\ 228.640\ PCORN_{t-1} - 16.025\ BPV_t + 208.220\ BPV_{t-1} - 8.314\ Y_t$$
$$(-.806) \qquad (-.093) \qquad (.969) \qquad (-1.984)$$

$$+\ 5.843\ Y_{t-1} + 4.988\ PFED_{t-1} - 54.880\ PCOW_{t-1}$$
$$(1.490) \qquad (.122) \qquad (-.602)$$

$$-\ 15.296\ PFEED_{t-1} - .199\ QFED_{t-1} - 34.984\ PGOOD_{t-1}$$
$$(-.382) \qquad (-1.016) \qquad (-.537)$$

$$-\ .211\ PLAC_{t-1} + .571\ TOTNF_{t-1}$$
$$(-.233) \qquad (4.317)$$

$\bar{R}^2 = .931$ $\qquad$ Sy = 231.885 $\qquad$ DW = 2.645

Table 12. Predicted Values from Reduced Form Equations.

		Variables					
YEAR	QTR	$\hat{QFED}$	$\hat{PLAC}$	$\hat{TOTNF}$	$\hat{PFED}$	$\hat{PFEED}$	$\hat{PCOW}$
1973	1	6779.000	5506.000	1883.000	43.280	50.770	30.670
1973	2	6435.260	5125.320	1894.070	35.126	40.440	26.038
1973	3	6410.000	5242.490	2114.850	35.019	39.719	25.023
1973	4	6165.350	6158.630	2325.290	31.400	37.596	22.926
1974	1	6600.790	4039.400	1925.720	30.206	34.112	22.127
1974	2	6479.330	3852.550	2570.170	28.462	29.673	19.534
1974	3	5697.770	4285.410	3542.450	28.569	25.302	16.173
1974	4	5176.410	5198.270	4661.070	26.348	19.054	12.171
1975	1	5612.770	4058.850	4232.350	23.501	16.762	11.627
1975	2	5602.270	4666.140	4431.130	26.538	19.969	13.242
1975	3	5492.500	5003.700	4822.040	28.643	22.313	13.912
1975	4	5675.370	6788.770	5381.030	24.871	22.214	12.765
1976	1	6175.240	4831.750	4325.950	26.009	23.864	14.823
1976	2	6194.680	4841.310	4307.390	25.386	24.671	15.630
1976	3	6391.270	5365.770	4173.560	23.714	24.278	15.493
1976	4	5888.370	6992.380	4826.450	20.879	20.084	12.088
1977	1	6546.510	5234.110	3923.150	24.308	23.943	14.995
1977	2	6274.930	5451.120	3969.810	23.795	23.865	15.037
1977	3	6406.050	5826.310	4035.260	22.116	22.373	13.878
1977	4	6052.530	7085.070	4384.210	23.172	23.973	13.796
1978	1	6956.700	5338.370	3182.110	24.305	25.768	16.455
1978	2	6430.740	5296.200	3175.620	26.247	28.000	17.948
1978	3	6828.530	5962.350	2828.840	27.340	32.793	20.207
1978	4	6568.980	7107.060	2864.840	27.426	33.259	20.012
1979	1	6885.780	5290.970	1751.740	30.357	37.999	23.602
1979	2	6195.370	5107.010	1882.470	35.536	43.244	26.497
1979	3	6413.610	5194.610	1914.360	30.411	37.827	22.773
1979	4	6014.210	6633.930	2495.460	27.082	33.158	19.681
1980	1	6508.650	4497.210	1771.760	26.700	31.952	20.160
1980	2	6060.020	4644.650	2134.830	25.284	28.766	18.279
1980	3	5973.040	5475.420	2744.660	27.630	28.872	17.667
1980	4	5826.930	6479.130	2980.170	26.424	28.460	17.068
1981	1	6325.950	4437.930	2332.450	24.372	26.561	16.728
1981	2	5859.270	4739.500	2733.830	25.288	24.416	16.161
1981	3	6147.170	5311.930	2978.150	23.961	23.135	14.786
1981	4	5735.720	6666.660	3110.390	22.983	24.034	13.908
1982	1	5982.750	4720.180	2539.060	22.992	24.452	14.382
1982	2	5905.420	5081.270	2704.090	23.726	22.830	14.749
1982	3	6109.770	5551.150	2908.090	22.897	22.694	14.076
1982	4	6088.600	6936.240	2933.120	20.194	22.544	12.921
1983	1	6357.640	4640.790	2621.330	20.749	21.630	13.226
1983	2	6275.790	5062.420	2602.760	20.632	21.239	14.054
1983	3	6497.820	5480.530	2876.770	21.708	21.811	13.880
1983	4	6165.380	6688.720	3280.290	20.143	20.717	12.152

Table 12--continued.

		Variables					
YEAR	QTR	$\widehat{QFED}$	$\widehat{PLAC}$	$\widehat{TOTNF}$	$\widehat{PFED}$	$\widehat{PFEED}$	$\widehat{PCOW}$
1984	1	6593.150	4954.060	2562.990	20.540	21.630	13.607
1984	2	6135.870	5057.170	2849.770	22.705	22.381	14.394
1984	3	6390.300	5462.010	3206.180	19.980	20.625	12.542
1984	4	6377.920	6808.860	3237.690	17.923	19.830	11.464
1985	1	6685.340	4919.890	2365.580	18.262	20.736	12.757
1985	2	6499.450	5058.270	2300.740	19.090	21.450	13.440
1985	3	6333.430	5538.340	2921.080	17.450	18.351	11.311
1985	4	6098.690	7072.680	3118.130	16.926	18.430	10.674
1986	1	6629.300	4915.600	2346.100	17.689	18.611	10.907
1986	2	6446.720	5282.500	2514.620	18.390	19.903	12.266
1986	3	6540.420	5825.320	3226.520	15.194	17.464	10.039
1986	4	6428.250	7006.320	3070.730	16.501	19.458	10.969
1987	1	6539.410	5212.900	2341.710	17.839	21.989	12.234
1987	2	6431.890	5258.580	2506.700	20.139	22.419	13.552
1987	3	6577.310	5813.670	2685.190	19.517	22.043	13.082
1987	4	6640.300	6987.270	2477.140	18.693	23.009	13.459

APPENDIX C

REDUCED FORM

The reduced form of the beef model is obtained by solving the structural equations for the endogenous variables. The system of nine cattle price and supply equations can be written in matrix form as:

$$\beta Y_t = \alpha Y_t(L) + \Gamma X_t(L) + u_t \qquad \text{(C.01)}$$

where

$Y_t(L)$ = P x 1 vector of lagged endogenous variables with lags beginning in period 1.

$X_t(L)$ = K x 1 vector of lagged exogenous variables with lags beginning in period 0.

u_t = G x 1 vector of disturbances.

Y_t = G x 1 vector of contemporaneous endogenous variables.

α = G x P matrix.

Γ = G x K matrix.

β = G x G matrix.

Solving equation (5.01) for Y_t yields

$$Y_t = \beta^{-1}\alpha Y_t(L) + \beta^{-1}\Gamma X_t(L) + \beta^{-1}u_t \qquad \text{(C.02)}$$

or

$$Y_t = \Pi_1 Y_t(L) + \Pi_2 X_t(L) + V_t \qquad \text{(C.03)}$$

The reduced form coefficients, Π_1 and Π_2, are presented in Table 13.

able 13. Reduced Form Coefficients.

ndogenous ariables	BPV	BPV-1	Y	E(PFED-1)	E(PGOOD-1)	E(PFEED-1)	PCORN	PLAC-1	PLAC-2	INT	E(QFED-1)	E(QNFSH-1)	E(QCOW-1)	E(QCOW-2)	D2	D3	D4	CONSTANT	E(PLAC-1)	E(TOTNF-1)	E(PCC
	<----- Exogenous Variables -----																				
PFEED	4.250	-2.673	-.006	.511	-0-	.518	-.424	-.001	-0-	-.037	-.001	-0-	-0-	-0-	-.328	-1.622	-1.312	12.441	.001	-.001	-
PLAC	293.032	-184.269	-.424	35.229	-0-	-38.263	-455.884	-.032	-0-	-36.868	-.063	-0-	-0-	-0-	1321.506	1744.667	2696.844	1556.099	.768	-.038	-
PFED	5.507	-3.463	-.008	.662	-0-	-.011	-.128	-.001	-0-	-.010	-.001	-0-	-0-	-0-	-.653	-1.784	-1.645	22.553	.215E-03	-.001	.
QFED	-0-	-0-	-0-	-0-	-0-	-0-	-0-	.323	-0-	-0-	.648	-0-	-0-	-0-	61.109	258.280	-150.220	393.230	-0-	-0-	.
PGOOD	5.482	-3.401	-.010	-.013	.589	-.015	-.174	-.001	-0-	-.014	-.001	-0-	-0-	-0-	-.574	-1.706	-.651	25.247	.292E-03	-.001	.
QNFSH	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-.449	.220	-0-	-0-	.935	-0-	-0-	-478.260	-160.520	-65.597	1490.000	-0-	-0-	.
PCOW	3.363	-.150	-.020	.029	-0-	-.031	-.370	-.256E-04	-0-	-.030	-.514E-04	-0-	-0-	-0-	-.424	-1.191	-1.404	26.017	.001	-.002	.:
QCOW	50.228	135.996	-1.393	-26.000	-0-	-31.471	-4.192	.023	-0-	-.506	.047	-0-	1.593	-.653	537.938	725.451	669.889	1217.292	.011	-.145	14.
TOTNF	-113.245	71.213	.164	-13.615	-0-	14.787	176.181	.012	-0-	14.248	.025	-0-	-0-	-0-	433.741	583.556	710.278	627.430	-.297	.979	.