QUARTERLY SIMULATION MODEL OF THE UNITED STATES LIVESTOCK-FEED GRAIN ECONOMY

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UNITED STATES LIVESTOCK-

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PREFACE

In the course of completing the research reported in this thesis, many persons made contributions worthy of recognition. The author is indebted to Dr. Daryll E. Ray, as major adviser, for his sound guidance throughout the completion of this project. Other members of my committee, Dr. Harry P. Mapp, Jr., Dr. Leo V. Blakley, Dr. Frank G. Steindl, and Dr. H. Evan Drummond, also provided helpful suggestions toward a successful research project.

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CHAPTER I

INTRODUCTION

Producers of agricultural commodities in the United States have been confronted with economic disruptions from several sources in the 1970's. The general economy of the U. S. during the 1960's was characterized by fairly stable growth in personal income and relatively low rates of inflation. Real economic growth has continued through the 1970's but has been accompanied with higher levels of inflation. These factors have affected both the level and stability of demand for farm commodities. Inflation has also contributed to increasing costs for farm inputs.

Agricultural exports in the 1970's have caused markets to become more volatile. Due to poor grain harvests abroad and an apparent greater willingness by some countries to supplement domestic production shortfalls with imports, U. S. exports of grain in recent years have shown dramatic increases over earlier years. The history of wheat exports exemplifies this change in foreign demand. From 1972 to 1975 wheat exports amounted to an average of 82.8 million tons annually compared to an average of 46.0 million tons during the ten years preceding 1972 (27). These exports, of course, have been welcomed by U. S. producers but have caused production needs to be less predictable.

Another notable change of the early 1970's has been the gradual decline of government involvement in agriculture. In the 1960's the federal government heavily influenced crop output through the use of acreage control programs. Large stockpiles of grain accumulated as a result of price support operations. These stockpiles were liquidated in the 1970's through policy adjustments, increased export activity and production shortfalls. As government reserves became negligible, market prices climbed and the importance of price support operations diminished. Increases in agricultural input prices also tended to make the established target prices and loan rates ineffective as a floor for income support. Through this period producers became more reliant on the marketplace as the principal source of income.

The high market prices for grains during the 1973-1975 interval seemed to create a feeling among part of Congress and the American public that governmental support of commercial agriculture might not be necessary in years to come. However, the market developments of 1976 and 1977 have cast doubt on this hypothesis. Grain stocks have risen to burdensome levels as producers have again proven that overcapacity of U. S. agriculture still exists.

The current situation in U. S. agriculture has led to renewed interest in legislating policies toward the support and stabilization of farm income. To determine policies which are both equitable and politically feasible requires an understanding of the relationships among the various subsectors of agriculture. Any policy change affecting one commodity must necessarily carry a secondary impact to other commodities as different subsectors compete for the same set of resources. Economic and statistical tools which aid in quantifying hypothesized relations become necessary in providing information regarding expected outcomes of policy action.

This study is concerned with two closely related subsectors of U. S. agriculture, livestock and feed grains. The crops included under the general term of feed grains are corn, grain sorghum, barley and oats. In the animal feeding process all of these grains are close substitutes. The livestock categories for the model are limited to those comprising the major portion of meat consumption in the United States and include cattle, hogs, and broiler chickens. Although livestock and feed grains do compete for some of the same resources, the major linkage between these two sectors is the use of feed grains as a primary input in livestock production. For all components of the livestock industry feed grains are required as a major input. Due to biological processes the substitutability between grains and other forms of feed such as roughage and protein supplements is limited. The other categories of demand for feed grains include seed, food, industrial, exports and storage. The domestic livestock industry competes directly with these other demand sources for the available feed grain supply. Because the livestock industry accounts for 60 to 75 percent of total annual feed grain disappearance, its importance to feed grain producers is clearly evident.

The extreme fluctuations in the grain markets in the 1970's necessitated adjustments of large magnitude in the production of livestock within the U. S. This was an unusual situation for producers who had grown to expect adequate supplies of grain at reasonably stable prices. Given the recent experiences of the livestock-feed grain economy, a data base has been generated which permits the study of economic response under very diverse situations. This information, if properly utilized, could supply the knowledge which would allow policy maker and economic entities within the livestock-feed grain sector to more adequately deal with economic disruptions occurring in the future.

Through a statistically oriented modeling approach, this study sets forth to construct a mathematical representation of the economic interrelationships within the livestock-feed grain economy. Several models of this agricultural subsector have been previously estimated. However, the period over which data were available at the time of estimation severely limits the applicability of most of these models to current developments. For example, the exports of grain were low in the 1960's compared to more recent levels. This led many modeling efforts to consider feed grain exports in a minimal context. As exports become a larger component of total demand, improved modeling of foreign markets is necessary to provide better outlook information and evaluation of policy alternatives. Inflation and its effect on output response in the livestock-feed grain sector is another factor which if considered at all, has largely been handled in a rudimentary fashion in previous modeling efforts. Again, this outcome must be considered dependent on the time periods used in analysis and estimation. Under the present economic scenario, inflation must be included as a principal factor influencing output.

Review of Literature

Several completed part studies have attempted to develop agricultural models related to the livestock-feed grain sector for either policy analysis and/or projection purposes. Although none of the research efforts reviewed herein is directly comparable, they all have had some influence on this project due to the similarity of the area of study or methodological framework pursued.

A 1973 dissertation by Rahn (15) was intended for use as an outlook information model over the short and intermediate runs for five meat industries: beef, pork, lamb and mutton, broiler chickens and turkey meat. Rahn's model is a set of econometric relationships estimated with quarterly data. Feed production and prices were treated as exogenous variables to the livestock industry. The model structure is recursive except for a five-equation block which determines wholesale prices for each meat category. The econometric equations were combined into a computer program capable of simulating quarterly meat output and prices for any number of periods, given exogenous variable values and beginning values for endogenous variables.

In a U. S. Department of Agriculture technical bulletin, Crom (3) reports the results of an econometric study of the beef and pork industries. Similar to Rahn, feed production and prices were designated as exogenous to the model. Calendar quarters were the time period of estimation and estimated parameters were incorporated into a simulation model. Unlike Rahn, Crom used his model to determine policy impacts on meat production and resulting prices as well as for projection purposes.

In a 1976 economic report, Womack (47) developed an annual supply-demand model for feed grains. In this work, each feed grain crop was treated separately rather than being aggregated into one commodity. Livestock production and value enter Womack's model exogenously. The major objectives for this model were short-term forecasting and policy analysis. The principal contribution made by this effort is an improved understanding of the interrelationships within the feed grain complex and its relationship to other sectors in agriculture.

An aggregate model of U. S. agriculture is provided in an unpublished dissertation by Trapp (23). His method of analysis was parameter estimation through econometrics to provide the information necessary to build a simulation model. With his work, Trapp attempts to measure many of the relationships within commercial agriculture. In comparison to the other studies listed, a more conscious effort is made to develop the linkages of agriculture to the overall economy through variables such as inflation rates, domestic incomes, population and foreign incomes. The intended purpose for this model is to provide a base for intermediate and long-term planning and policy proposals.

Both Trapp and Womack made extensive use of some previous work in the area of crop supply analysis. In 1972, Houck and Ryan (8) first reported the use of a methodology incorporating both government price supports and acreage restrictions into one price response variable for corn production. Their success precipitated several supply studies for other crops (9) (19) (46). The approach used by Houck and Ryan significantly improved prediction accuracy for crop production for years when government programs were the dominant force in determining crop acreage. However, some modification of their method appears necessary to account for acreage variation in years when market prices are high relative to support rates.

Several other related studies have been reported, but due to specific areas of interest or modeling approaches undertaken, their effects on the direction of this study were limited. Heien, Kite and Matthews (6) constructed an annual model of the beef and pork sectors of U. S. agriculture to project livestock related variables in conjunction with a larger modeling effort. In an unpublished dissertation Talpaz (21) constructed a pork model based on analytical results obtained on the pork cycle via spectral analysis. Another model which included several livestock sectors was completed by Freebairn and Rausser (4). This study was used to extensively evaluate the impact of U. S. beef import policy. In addition, Shuib and Menkhaus (20) estimated an annual model of the beef-feed grain economic structure to provide parameter estimates as a basis for making policy conclusions.

Objectives

As new agricultural policies to deal with low farm incomes and market instability come under consideration, there arises a need for economic tools to estimate the impacts of proposals for both the short and long runs. Also, with agricultural markets trending toward more instability, uncertainty causes problems in making efficient production decisions. The need for improved outlook information to facilitate firm decision-making becomes evident.

The main purpose of this research project is to estimate the relationships between the livestock and feed grain sectors over quarterly and annual time periods. Through this effort a quarterly simulation model which is capable of projecting prices and outputs is to be developed. More specifically, subobjectives to be included are:

1. Measure the impact on domestic livestock and grain markets of increasing the level of feed grain exports.

2. Measure the impact on the domestic livestock industry and feed grain demand of changing the level of beef imports.

3. Analyze short and long run impacts on crop and livestock production of a change in support rates and diversion payment policies offered by the federal government.

4. Analyze the economic effects of exogenous increases in variables such as the yield of corn, per capita income and higher prices in the general economy.

5. Provide five-year projections of output and prices for the livestock-feed grain sector under an assumed scenario for exogenous conditions affecting U. S. agriculture.

Thesis Organization

Chapter II presents the economic theory underlying the specification of the model. Also included is a description of the hypothesized structure of the livestock-feed grain economy along with an explanation of the various forms of parameter estimation which were employed.

Chapter III reports the results of parameter estimation for all segments of the model. Chapter IV discusses the various tests used in model validation and presents the analytical results.

Chapter V demonstrates the use of the model in policy analysis and provides impact estimates for various changes in exogenous variables. In addition Chapter V includes results of five-year projections made with the model under an assumed scenario.

Chapter VI summarizes the research effort and offers some suggestions which could prove helpful to someone attempting research in similar or related areas.

CHAPTER II

THEORETICAL AND METHODOLOGICAL DIMENSIONS

This research is a study of the relationship of two subsectors of U. S. agriculture. As such, macro-type variables such as total output in each sector, population and incomes are important variables within the model. Empirical model specification of the output response to prevailing prices, however, is premised on individual firm behavior. Thus, the model specification is one of aggregate output based on behavior at the micro level. Marco relationships are considered within the model, but only as they affect prices received by producers, which result from the interaction of aggregate supply and demand.

Theoretical Basis of Specification

Microeconomic Theory of the Firm

The livestock and grain producer both strongly resemble the case in micro-economic production theory of a firm operating under pure competition. The producers of agricultural commodities are generally small in relation to the market as a whole and cannot measurably effect the prices received for output or prices paid for inputs. Under the assumption of profit maximization with numerous products and inputs, a general specification for optimal output in a static sense may be derived as follows (see Henderson and Quandt (7) for more thorough coverage).

Equation (1) represents an implicit production function for a firm with m outputs and n inputs.

$$f(q_1, q_2, \ldots, q_m, x_1, x_2, \ldots, x_n) \tag{1}$$

The profit function is given by equation (2) with input and output prices assumed constant for the firm.

$$\pi = \sum_{i=1}^{m} p_i q_i - \sum_{j=1}^{n} r_j x_j \tag{2}$$

Putting equation (2) in a form to maximize profits subject to the technical constraint of the production function yields equation (3).

$$J = \sum_{i=1}^{m} p_i q_i - \sum_{j=1}^{n} r_j x_j + \lambda f(q_1, \ldots, q_m, x_1, \ldots, x_n) \tag{3}$$

To solve for first order profit maximization conditions, partial derivatives of the function are taken with respect to each input, output and the constraint function and set equal to zero to yield equations (4), (5), and (6).

$$\frac{\partial J}{\partial q_i} = p_i + \lambda f_i = 0 \tag{4}$$

$$\frac{\partial J}{\partial x_j} = -r_j + \lambda f_{m+j} = 0 \tag{5}$$

$$\frac{\partial J}{\partial \lambda} = f(q_1, \ldots, q_m, x_1, \ldots, x_n) = 0 \tag{6}$$

Assuming that second order conditions are fulfilled (which insures the optimum to be maximum), several relationships among inputs, output, and prices may be derived.

The rate at which one output may be substituted for any other output equals the ratio of the output prices.

$$\frac{p_t}{p_s} = \frac{f_t}{f_s} = \frac{\partial q_s}{\partial q_t} \quad (t, s = 1, \ldots, m)$$

The value of the marginal product of each input for each output is equal to the input prices.

$$r_j = p_i \frac{\partial q_i}{\partial x_j} \quad \begin{matrix} (j = 1, \ldots, n) \\ (i = 1, \ldots, m) \end{matrix}$$

The rate at which one input may be substituted for any other input in a given production process is equal to the ratio of input prices.

$$\frac{r_y}{r_z} = \frac{f_{m+y}}{f_{m+z}} = \frac{\partial x_z}{\partial x_y} \quad (y, z = 1, \ldots, n)$$

From these derived relations one may hypothesize that the aggregate output of an agricultural commodity is functionally related to its own price, prices of other agricultural commodities and input prices. Over the long run output of a commodity would also be a function of technology in its production process relative to other commodities competing for agricultural resources.

Short Run Relation of Feed Grains and Livestock

In developing the theoretical relation between livestock and feed grain production, feed grains are viewed as an input to livestock production. Over the period of a quarter, the number of animals cannot vary appreciably so that the quantity of animals may be assumed fixed.

Equation (7) displays a simplified profit function for a livestock producer with one variable input, grain (g), one fixed input, livestock to be fed (1), and one output, finished livestock product (L).

$$\pi = PL - r_1 g - r_2 1 \tag{7}$$

Assuming livestock to be fed is constant for the time period considered and a general production form which includes both grain and livestock, equation (8) may be derived from equation (7).

$$\pi = Pf(g) - r_1 g - C \tag{8}$$

Solving for first order conditions yields equation (9), and further algebraic manipulation obtains equation (10), representing the short run demand for feed grains.

$$Pf_1(g) - r_1 = 0 \tag{9}$$

$$g = \frac{r_1}{P} (f_1^{-1}) \tag{10}$$

Since livestock to be fed is involved as a fixed quantity in the production function for the finished livestock product, the demand for feed grains as an input in the short run may be stated in general form as:

feed grain demand = f(units of livestock to be fed, price of finished livestock, price of feed grains)

Real World Application: Divergence from Theory

Microeconomic theory of the firm forms a basis for empirical estimation of relationships within the livestock-feed grain economy, but some consideration should be made for differences between theoretical assumptions and reality. One assumption of perfect competition is that markets are free of artificial constraints. For commercial agriculture there is an obvious exception to this via federal government influence on crop production. Domestic crop supply functions approximating reality must, therefore, take into account both prices to which supply responds and the restrictions imposed by government regulations.

Traditional micro theory also assumes a static world within which economic entities function. In actuality economic processes are dynamic and require time for completion. Variables which represent the true nature of the systems might reflect human behavioral lags in response to economic stimuli, biological lags due to the inherent characteristics of the production scheme or the lack of mobility of resources between enterprises. In a modeling framework the dynamics of the economic system are often introduced by using lagged forms of the variables to which output responds, in contrast to using the current values suggested by traditional micro theory.

A third assumption of perfect competition which is not completely met in the real world concerns the knowledge of input and output prices. Microeconomic theory generally assumes input and output prices are fixed and perfectly known to all the individual firms in the industry. In commercial agriculture input and output prices may be safely presumed fixed for each firm, and input prices are likely known with some degree of certainty. However, much uncertainty exists for market participants in anticipating output price at the time production plans are made. Risk and uncertainty in the determination of expected output prices arise from imperfect knowledge concerning current and future market conditions, highly variable export demand for U. S. agricultural commodities and the crucial role of weather in agricultural production. Due to the uncertainty involved in planning output, the price to which supply responds is some form of aggregate expected price based on individual expectations weighted by the production capabilities of each firm. In modeling aggregate behavior, the effects of imperfect knowledge is commonly treated by using expectational forms of price variables to project future output.

Specification and Estimation

Hypothesized Structure of Livestock-Feed Grain Economy

In modeling the structure of any economic sector, the time period of analysis is an important consideration in terms of both specification and statistical estimation. The principal form of data used for this project is quarterly time series. This length of observation period permits a recursive specification for a major portion of the structural relationships included in the model. By using a recursive formulation, many of the statistical problems encountered in a simultaneous framework may be avoided.

To ascertain whether values of economic variables are determined sequentially (and may therefore be specified as recursive) or simultaneously, an understanding of the nature of the economic system is necessary. The output of grain crops during a given quarter is affected very little by demand and supply conditions in the market place during the same quarter. Rather, grain output for any quarter is primarily a function of the market situation at the time planting decisions are made. Similarly, time lags are also inherent in livestock production systems. Although current market prices during a quarter can affect livestock and meat output, the influence is presumed to be very limited. In general, the shorter the time period of analysis, the more likely decisions which determine the current values of economic variables are based on market information in past periods. Given the quarter as the observation period, grain and livestock current supplies are both assumed to be predetermined.

A flow diagram of the major linkages within the livestock-feed grain sector is displayed in Figure 1. The direction of causality or flow is indicated by the connecting arrows. As previously indicated most variable values are quarterly and are assumed to be determined sequentially. Because some of the data required to estimate the model are not reported on a quarterly basis and a few relationships are specified as simultaneous, some explanation of Figure 1 is necessary.

Data for the feed grain segment of the model are reported on the basis of crop year quarters. In this framework, the year is divided as follows:

Quarter 1: October, November, December

Quarter 2: January, February, March

Quarter 3: April, May

Quarter 4: June, July, August, September

Feed grains are actually harvested only once each crop year but at different times within the year according to grain type. Corn and grain sorghum which represent the bulk of feed grain production are harvested in the October-December quarter. Oats and barley are

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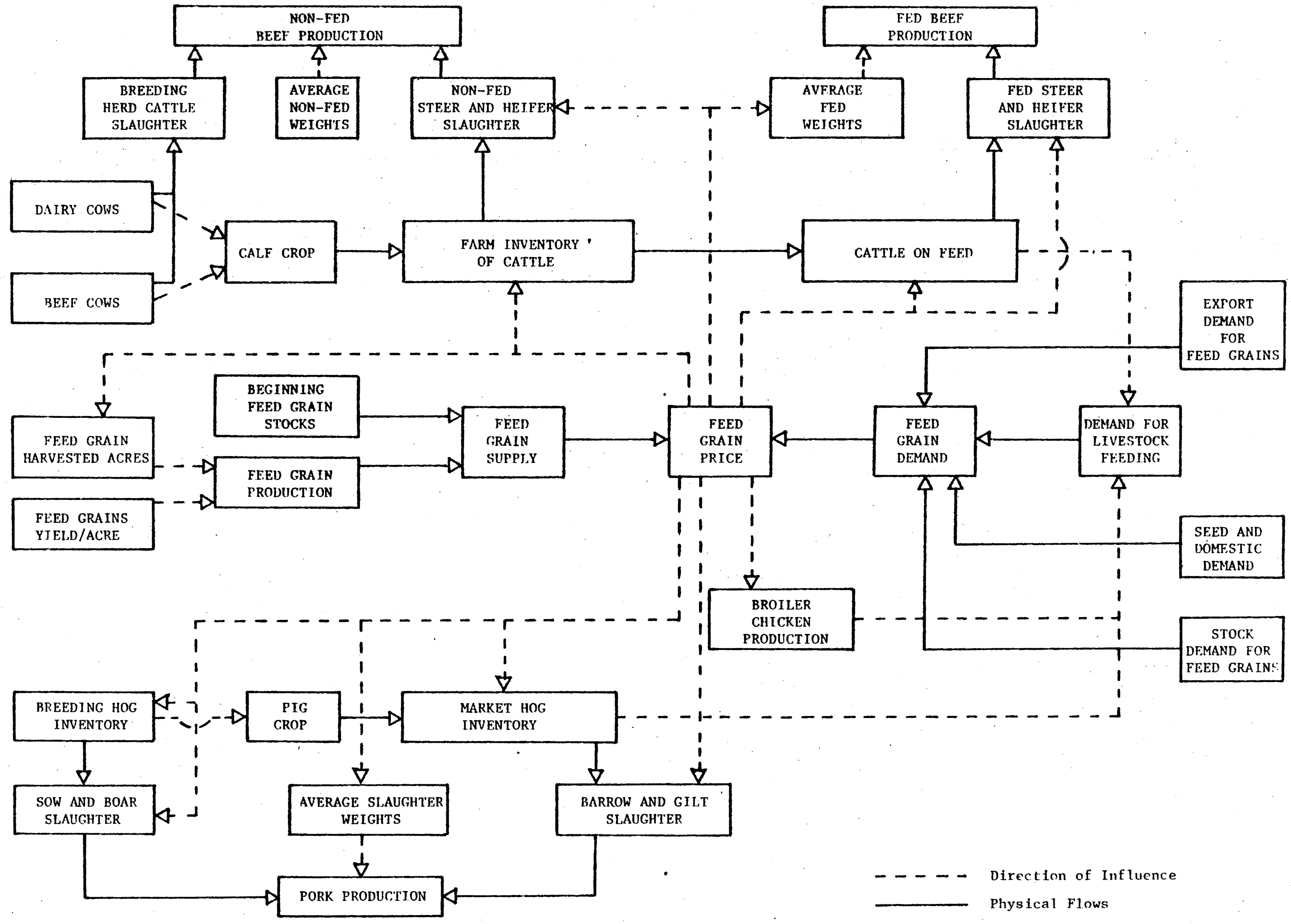

Figure 1. Flow Diagram of Relationships in the Livestock-Feed Grain Economy

harvested during the June-September quarter. Therefore, quarterly grain production is significant in only two quarters per year and is equivalent to the sum of annual grain production from each crop.

Feed grain production during a quarter when added to stocks on hand at the beginning of the quarter represents available grain supplies. As these supplies are placed on the market a price is determined by the competition among the set of demands. The quarterly demands for feed grains are assumed to be operating in a simultaneous structure, since all demand sources must be satisfied within the quarter.

Because cattle inventory data are reported only twice each year, the cow inventories which form the basis of the cattle subsector are defined as annual relationships. From the inventory of breeding animals is derived an annual calf crop. Depending on the profitability of feeding grain to cattle, calves on farms may be placed into feedlots for finishining or grazed until an acceptable slaughter weight is achieved. Quarterly beef production is then obtained from three live animal sources: breeding herds, non-fed steers and heifers, and grain-fed steers and heifers.

Because of the seasonal nature of pork production, hog inventories and pig crops are reported on a seasonal quarter basis in the following manner:

Quarter 1: December, January, February

Quarter 2: March, April, May

Quarter 3: June, July, August

Quarter 4: September, October, November

Analagous to the beef subsector, from the breeding hog inventories pig crops are produced. Hogs intended for marketing are then placed on grain until the desired slaughter weight is realized. Therefore, pork production is derived from two sources, breeding hogs and barrow and gilt slaughter.

The production of broiler chickens, although following the same biological pattern as beef and pork, is completed in a shorter time horizon. Thus, for a quarterly model, the structure may be specified in the more simplified manner shown in Figure 1.

Not shown in Figure 1 is the set of structural relations depicting market prices for meat and livestock. As meat and livestock quantities are assumed predetermined for the current quarter, the prices of meats are hypothesized to be determined simultaneously as consumers bid for available supplies. Live animal prices are then specified in a derived demand framework to be functionally related to meat price and marketing margins. The quantity of livestock being fed and the value of livestock are hypothesized to influence the current period demand for grains for livestock feeding. From the set of feed grain demand relations is derived a market clearing price which carries an impact on future livestock and meat output through its bearing on current period planning decisions.

Methodology of Estimation: Econometrics

Most of the economic parameter estimates reported in this study were estimated through econometric analysis. The three primary techniques employed were ordinary least squares, autoregressive least squares and two-stage least squares. Although these techniques are widely used and discussed in several textbooks, this section seeks to summarize the approaches and the situations to which they apply.

<u>Ordinary Least Squares</u>. In the ordinary least squares model, one assumes the true state of interrelationships between variables can be represented by a linear equation of the form:

$$Y_1 = XB_1 + U$$

In this case, Y_1 is the variable whose variation is assumed explained by X, where Y_1 is an nxl vector of observed values, X is an nxk matrix of observations on the independent explanatory variables, B_1 is a kxl matrix of population parameters and U is an nxl matrix of random errors.

With least squares, the estimator for B_1, $\hat{B}_1$, is chosen such that the sum of the squared random errors is minimized. Mathematically this is accomplished by differentiating $U'U$ with respect to B_1. The estimator $\hat{B}_1$ derived in this manner is given in matrix form as:

$$\hat{B}_1 = (X'X)^{-1}X'Y_1$$

This model yields an unbiased estimator with the lowest variance of all linear unbiased estimators when the following set of assumptions hold (10):

1) $E(u_i) = 0$
2) $E(u_i u_i) = \sigma^2$
3) $E(u_i u_j) = 0,\ i \neq j$
4) $E(x_i u_i) = 0$

When one of these assumptions is violated, improved parameter estimates may often be achieved by some method other than ordinary least squares. A common problem encountered with time series data is autocorrelation which violates the third assumption of independent errors among observations. Autocorrelation with time series data is usually caused by the effects of the disturbance term in one period being carried into future periods. As might be expected, the shorter the period of observation, the more likely autocorrelation will be a serious problem.

Autoregressive Least Squares. If autocorrelated errors are present and ordinary least squares is used, parameter estimates are unbiased but lose in efficiency as the variance of the estimators increases (11). Estimation techniques designed to treat this problem assume a relationship exists between successive errors and this relationship then becomes part of the estimation process. Ordinarily errors are assumed linearly related in a first order autocorrelation scheme, where ρ describes the value of the relation between success errors.

$$u_i = \rho(u_{i-1}) + \varepsilon_1$$

Martin and Fuller (5) have formulated an iterative technique which provides for simultaneous estimation of equation parameters and the first-order autocorrelation coefficient, ρ. The computer program developed by Martin and Fuller also calculates the standard error of the autocorrelation coefficient as a test of its significance. A revised computer program employing the Martin-Fuller technique was used in this study to estimate regression coefficients whenever autocorrelation was suspected (17).

Estimation of Simultaneous Equations. When economic relationships are specified as a system of equations, and the values of variables involved in the system are assumed to be determined within the same time period, another problem in statistical estimation is encountered.

More specifically, when the explanatory variables in an equation within a system are correlated with the error term, the fourth assumption is violated. The use of ordinary least squares in this case yields estimators which are biased and inconsistent.

A single-equation estimation technique suggested to deal with this problem is two-stage least squares. The objective of this approach is to replace the explanatory variables which are correlated with the error term with variables independent of the error, but highly correlated with the original variables. The specification given below is representative of a single equation within a simultaneous system.

$$Y_1 = Y_2B_2 + XB_1 + U$$

Y_1, X, B_1 and U are as previously defined. Y_2 represents an nxg matrix of observations on explanatory variables which are correlated with U. B_2 represents a gxl matrix of coefficients for the Y_2 variables. The first stage of estimation provides a predicted variable, $\hat{Y}_2$, to substitute for Y_2 in the second stage of estimation. The predicted values are calculated by the following equation.

$$\hat{Y}_2 = X(X'X)^{-1}\, X'Y_2$$

The equation for the second state of estimation then becomes:

$$\begin{bmatrix} \hat{Y}_2{}'\hat{Y}_2 & \hat{Y}_2{}'X \\ X'\hat{Y}_2 & X'X \end{bmatrix} \begin{bmatrix} \hat{B}_2 \\ \hat{B}_1 \end{bmatrix} = \begin{bmatrix} \hat{Y}_2{}'Y_1 \\ X'Y_1 \end{bmatrix}$$

This approach leads to estimators, $\hat{B}_2$ and $\hat{B}_1$, which are consistent but biased in small samples (11).

A further complication arises when autocorrelated errors are involved in a system of simultaneous equations. One approach suggested to deal with this estimation problem is autoregressive two-stage least squares (16). The first stage involves purging endogenous explanatory variables of correlation with the error term by regressing on all the exogenous explanatory variables plus a one period lag of those same variables. In the second stage, the Martin-Fuller technique is employed to simultaneously estimate structural coefficients and the first order autocorrelation coefficient. This method yields estimators which are both efficient and consistent.

Systems Approach to Estimation

Within a production system for any good, inputs are combined through some process to derive a final product. The activity of production generally requires some amount of time to complete because of physical or biological limitations of the elements involved in product generation. In modeling a dynamic system, the time delays must be incorporated in an appropriate mechanism such that the model is in close harmony with the real world.

Econometrics is a convenient tool to simulate the operation of functions which may be described in terms of discrete delays. If an operation requires exactly Z periods to complete, current period employment of inputs may be used to project output Z periods hence. If the time delay is not precise or the time period of analysis is long in comparison to the production lag, econometrics can still perform adequately through the use of various distributed lag models (11). Depending on the nature of the lag, the flexibility of distributed lag models as a whole allows for an almost infinite number of weighting schemes with which outputs may be related to inputs. Therefore, econometrics may be viewed as furnishing a means of accurately estimating the average delay for a process.

Although the distributed lag concept can be useful in estimating lagged relationships, it has limitations in describing the dynamics of real world functions. The inputs into an econometric distributed lag are lumpy, occurring only once during each time period. If the observation period is relatively long, this may lead to inaccurate projection of the future value of the output variable. Also, the estimation of average delays is only one descriptive measure of an input-output relation. The conversion lag may be different for each unit of output and the average delay only provides an expected value for the timing of the output quantity. The variation around the average is not an explicit part of estimation in distributed lag formulations and becomes disguised as overflow into previous and succeeding time periods.

A technique has been devised which allows for a more thorough description of time delays in real world systems. When inputs are fed into a process continuously and/or units of output are subject to varying lags in conversion, this technique is more appropriate than econometrics in simulation modeling. The technique described is referred to an continuous delay modeling and has been incorporated into some computer programs designed for simulation such as Dynamo (14). With continuous delay modeling an exact value for the delay process is not assumed, rather output changes gradually as inputs are varied. The relation of outputs to inputs consists of both an average lag length and some variation around the average. The difference in the way output responds to inputs for a discrete delay compared to a continous delay is displayed in Figure 2. In Figure 2, an increase in the flow of the input variable is followed by a one time change in the flow of the output variable when a discrete delay is assumed. In contrast, the continuous delay distributes the change in the flow of the output variable over an interval.

The theoretical basis underlying the continous delay approach involves a system of differential equations and will not be discussed. A thorough presentation of the mathematics involved can be found in Manetsch and Park (13). Numerical techniques which approximate the exact methematical relationships have been programmed into computer subroutines so that the method may be easily incorporated with other simulation techniques in applied research.

<u>Numerical Methods for Simulating Continuous Delays</u>. Several Fortran subroutines capable of simulating continuous delay processes can be obtained in Manetsch and Park (13). One of the more simple formulations given by Manetsch and Park is listed below.

```
  SUBROUTINE DELAY2   (VIN, VOUT, R, DEL, DT, K)
  DIMENSION  R(1)
  KM1 = K - 1
  A = DT * FLOAT (K) / DEL
  DO 1 I = 1, KM1
1 R (I) = R(I) + A * [R(I + 1) - R(I)]
  R(K) = R(K) + A * [VIN - R(K)]
  VOUT = R(1)
  RETURN
  END
```

In the argument list of the subroutine, VIN and VOUT refer to the respective input and output quantities. The R represents storage values or quantities of input currently being processed. DEL gives the value of

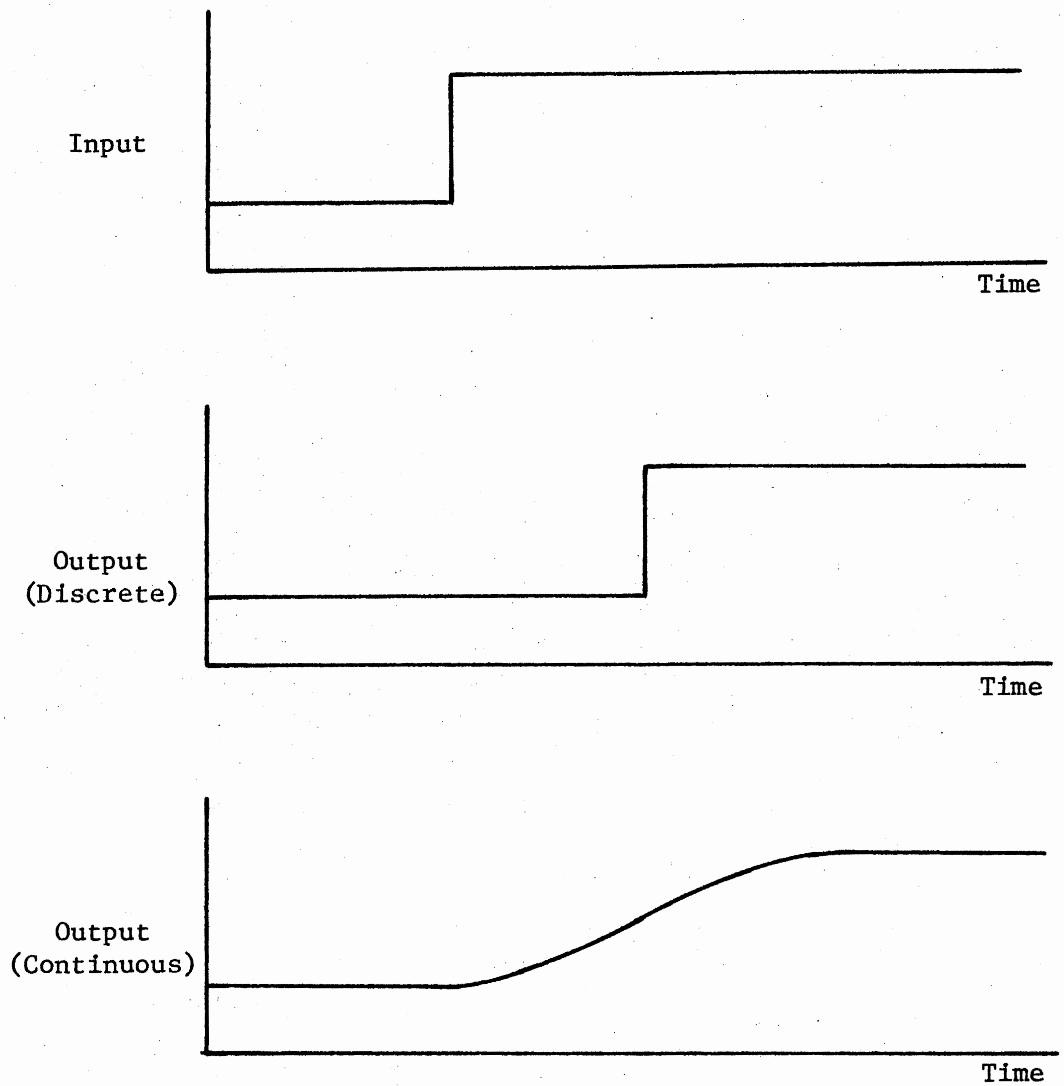

Figure 2. Comparison of Discrete and Continuous Change in Output From a Discrete Input Change

the average delay involved and DT is the time increment assumed for the model. K is referred to as the order of the delay and allows the user to specify the form of variation about the average delay assumed for the process.

Rather than attempting a thorough description of the internal operation of the subroutine, a numerical example was developed to demonstrate the relationship of outputs and inputs. The example provided simulates a delay in which a set of 100 inputs are injected into a system during the first period. No other inputs are added until all the units have been converted into an output flow. Figure 3 shows the relationships between inputs and outputs under this assumed framework.

Figure 3 demonstrates K to be the critical parameter in determining the distribution of output. The output form has the properties of the family of Erlang density functions given by:

$$f(T) = \frac{(aK)^K \ (T)^{K-1} \ e^{-KaT}}{(K-1)!}$$

The mean of this distribution is: $E(T) = \frac{1}{a}$ and the variance is: $Var(T) = \frac{1}{Ka^2}$ (13). DEL for the simulation subroutine is equal to the mean, $\frac{1}{a}$, and the K in the variance formula is the same K entering the subroutine. Thus, there is a close and well-defined relationship between the value given K and the distribution of output. The Erlang density function can assume a variety of shapes depending on the value assigned to K. In general, as K increases the density function becomes more symmetrical and concentrated near the mean. Therefore, this simulation approach offers the user a wide range of possible assumptions to be made regarding the nature of real world delays.

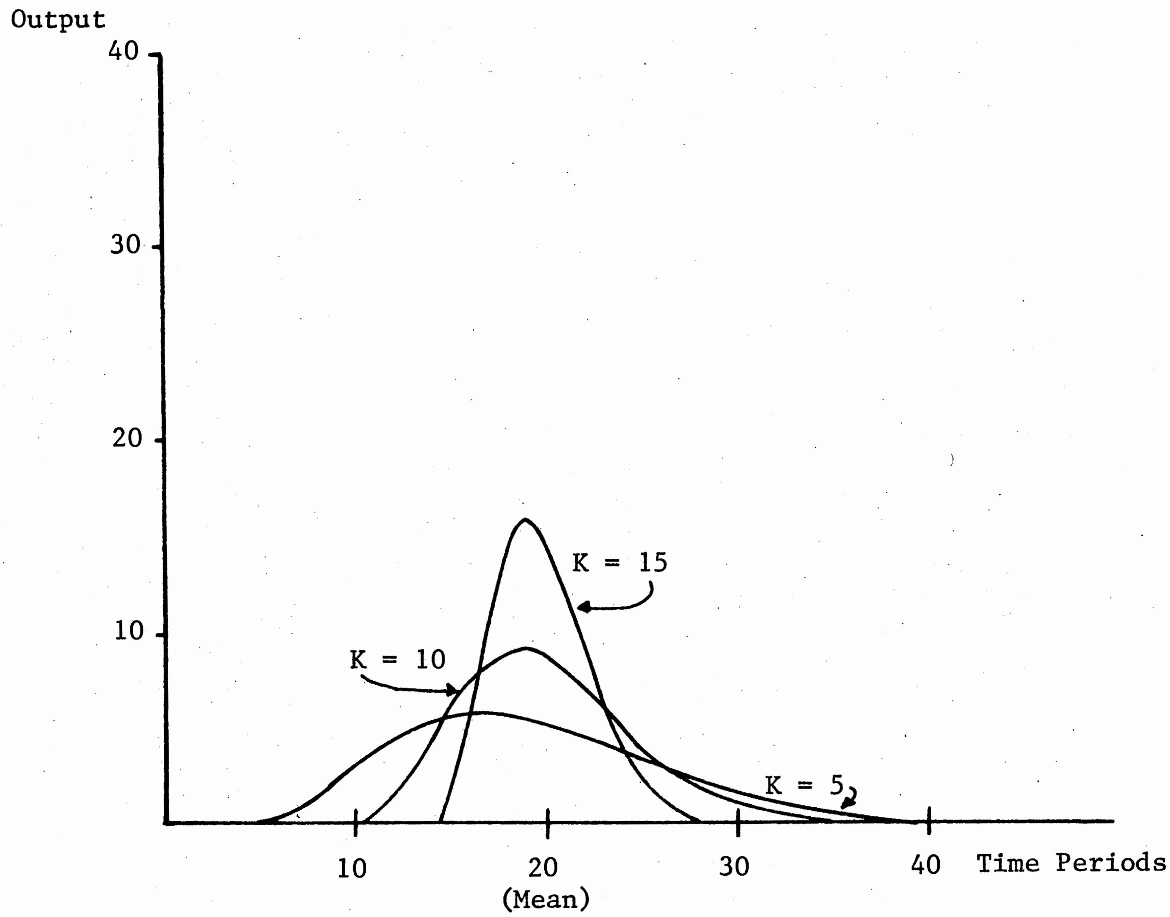

Figure 3. Output Distributions from a Continous Delay of a One-Time Inflow in the First Period

<u>Application to Pork Production</u>. Hog production represents a biological system for which continous delay modeling may have some application. Barrows and gilts intended to be marketed for slaughter must complete a growth and maturation process which requires time for completion. However, the time lag involved for each animal cannot be realistically assumed constant. Slaughter weights are subject to variation as are the genetic backgrounds which help in explaining growth rate differences. The growth rate can also be influenced by the quality and quantity of rations fed. These factors help support the use of a continuous delay modeling procedure to simulate the production of barrows and gilts for slaughter.

USDA published data classify hog inventories according to the intended use for the animals. The breeding hog inventory consists of all hogs used previously for reproduction or intended for that use in the future. The market hog inventory which accounts for the remainder of the hog population are those barrows and gilts which will be fed and slaughtered for pork production. The inflow into a hog production system includes barrows and gilts from the pig crop which will not be used in breeding. The outflow in hog production can be viewed as the slaughter of barrows and gilts. The lag in the conversion of newly farrowed pigs into mature animals ready for slaughter is a function of the realized growth rate and the finishing weight.

Figure 4 presents an overview of the market hog sector. Published data provide a breakdown of market hog inventories by weight. The primary difference between this biological system and most physical systems is the attrition from the flow of animals through the weight categories.

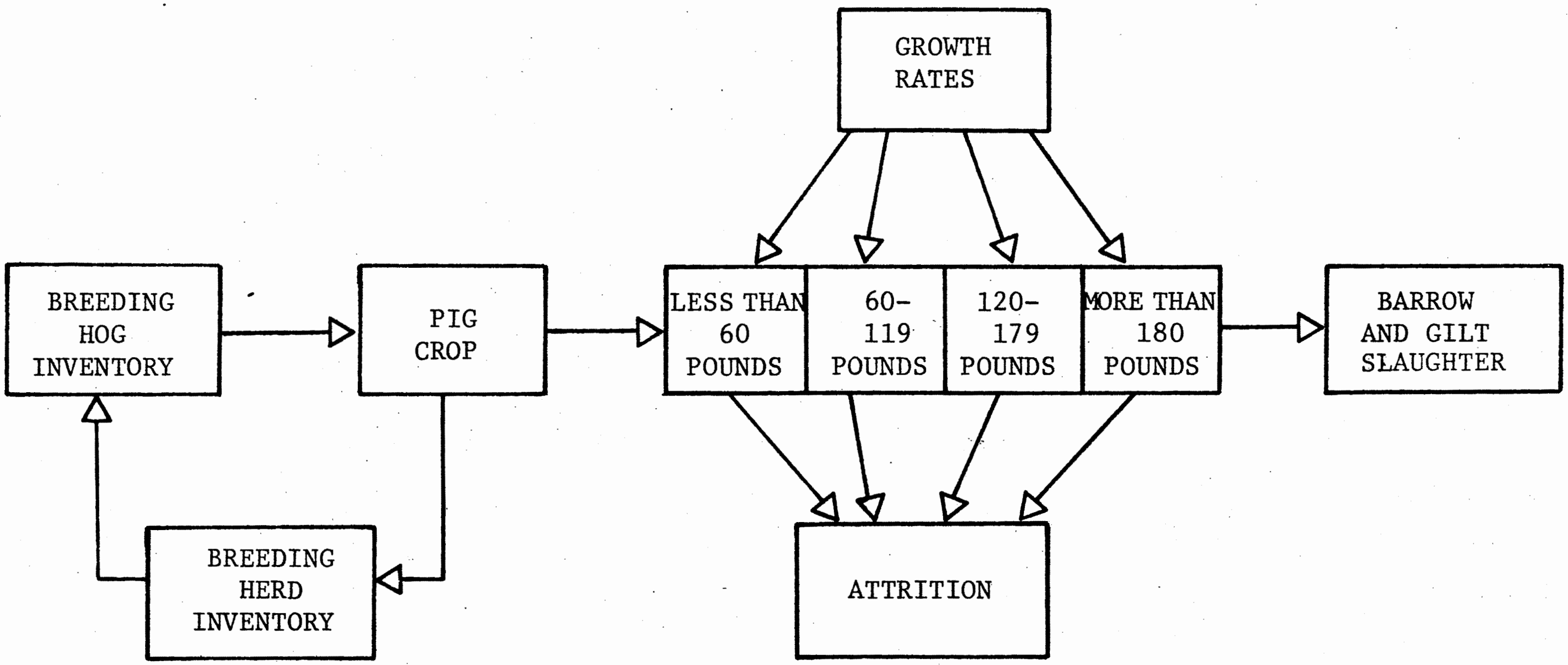

Figure 4. Flow Diagram of Market Hog Production System

Deaths and other losses cause the ending output of animal units to fall below the number entering. Some consideration of this continual leakage must be made in the modeling framework.

In applying the continuous delay modeling concept to hog production, information on the inflow, outflow, inventory of animals being fed and finishing weights can be derived from published data sources. The other information necessary to operate this model include: growth rates of animals (average delay), variation in growth rates and attrition of animals being fed. This knowledge is not readily available, but procedures have been developed which make possible the estimation of these parameters needed to generate output projections from known input levels.

Optimal control theory provides a means of estimating historical values of average hog growth rates and attrition rates in the hog production system. As an applied mathematical technique, professional interest regarding the use of control theory in research is growing. For those interested in pursuing this topic in greater depth, a recent bulletin by Richardson, Ray, and Trapp (18) contains thorough discussion of control theory and some suggested optimization techniques. The major idea behind control theory is derived from the hypothesized relationships between variables in a system and the characteristics of those same variables. Some variables are exogenous and affect the output of the system but are uncontrollable. Another set of exogenous variables also affect output but may somehow be managed by the entity controlling the system. A third set of variables are the output variables which are determined endogenously in the system. In optimal control theory a subset of output variables is used in a performance measure for the model. An iterative procedure is used to determine the set of values for the control variables which optimizes the performance measure for the system.

In the hog production system described earlier, the two primary exogenous uncontrollable variables are slaughter weights for barrows and gilts and the newly farrowed pigs entering as model inflow. The output variables are barrows and gilts going to slaughter and the inventory of market hogs on feed. Two of the important unknowns, growth rates and attrition from market hog inventory, may be viewed as control variables. These two variables cannot be controlled in the real world, but they do control the rate of slaughter and the level of inventories. Thus, for purposes of prediction values for growth and attirtion may be exogenously supplied to accurately project market hog inventory and hog slaughter subject to exogenous inflow. Given an historical data set in which market hog inventories and slaughter rates are known, a performance measure can be devised which minimizes the error between model output and the true output of the system. In doing so, the optimal values of control variables during past periods may be estimated. These values may then be used in providing information regarding future values of growth rates and attrition rates which are most likely.

A recent study by Trapp (24) has applied this same technique to cattle on feed numbers. His approach to the modeling of cattle on feed is basically the same as the one described for market hogs. Animals enter the cattle on feed inventories as placements. Similarly, a finishing weight is achieved within the system at which time the animal is slaughtered. The only major difference in the hog and cattle structures is the point at which inflow is allowed. For hogs, all newly born pigs enter at the same beginning weight. Placements enter cattle on feed at a variety of weights, ranging from 300 to 900 pounds. Thus, with cattle on feed both placements and weight of placements become control variables for the projection model.

CHAPTER III

ESTIMATION RESULTS

This chapter reports the results of parameter estimation for the various subsectors of U. S. agriculture being analyzed in this research. Variable names and the unit of measurement are listed in Table I. An "(X)" following a variable name indicates a variable exogenous to the model. A discussion of the justification for the specification is included with each equation or set of equations.

A subscript of t-i refers to a lagged relationship of i periods in length. Under each coefficient is given the t-statistic to test the null hypothesis: $\beta = 0$. Also included with each estimated equation are the R^2, giving the proportion of variation in the dependent variable explained by the equation, and the Durbin-Watson d-statistic, which furnishes a test of autocorrelation in the residuals. The equations of the model were estimated with different numbers of observations depending on data availability. The period of estimation is included with the discussion of each equation.

Feed Grains

The production of feed grains in the U. S. consists of the sum of the production of four major field crops: corn, grain sorghum, barley and oacts. In terms of production these four grains were treated as separate crops in attempt to isolate competitive relationships. Annual

TABLE I

DEFINITIONS OF VARIABLE NAMES USED IN REPORTED RESULTS

Variable Name	Description	Units
ANUNIT(X)	Animal units in EC-6 countries, United Kingdom and Japan (1.0 * cattle; 0.4 * hogs)	Mil. Units
APIX	Price index to measure the value of animals fed (.428 * (SSPIX) + .476 * (PBGIX) + .096 * (BFPIX))	
BBYPRD(X)	Value of edible and inedible by-products of beef processing	$/cwt.
BCI	Beef Cow Inventory (Jan. 1)	Thous. Head
BEDVD(X)	Barley effective diversion payment (deflated)	$/bu.
BEFSD(X)	Barley effective support rate (deflated)	$/bu.
BEXP(X)	Beef exports and shipment out of U. S.	Mil. lbs.
BFP	Broiler price received by producers	$/cwt.
BFPIX	BFP_t ÷ Average BFP, 1955-1964	
BGLVWT	Average live weight of barrows and gilts slaughtered	lbs.
BGS	U. S. commercial slaughter of barrows and gilts	Thous. Head
BHA	Barley harvested acres	Mil. Acres
BHI	U. S. breeding hog inventory for the end of quarter	Thous. Head
BIMP(X)	Beef imports to the U. S.	Mil. lbs.
BPR	Average barley price received by farmers	$/bu.

TABLE I (Continued)

Variable Name	Description	Units
BPROD	Annual barley production	Mil. Tons
BPROF6(X)	$[(PROF_{t-1} + PROF_{t-2} + PROF_{t-3} + PROF_{t-4} + PROF_{t-5} + PROF_{t-6}) \div 6.0] * \frac{BCI_t}{BCI_{1950}}$	
BPRLRD	Differences in crop year barley price (t-1) and loan rate for year t; minimum value = 0.0 (deflated)	\$/bu.
BREXP	Broiler exports and shipments out of U. S.	Mil. lbs.
BROILER	Domestic broiler production	Mil. lbs.
BROILERS	Domestic broiler supplies available for consumption	Mil. lbs.
BROILERSPC	Domestic broiler supplies per capita	lbs.
BSS	Commercial slaughter of bulls and stags	Thous. Head
BYLD	Barley average yield per acre	Cwt.
CEDVD(X)	Corn effective diversion payment (deflated)	\$/bu.
CEFSD(X)	Corn effective support rate (deflated)	\$/bu.
CHA	Corn harvested acres	Mil. Acres
COF	Cattle on feed in 23 states; end of quarter	Thous. Head
COF23	January 1 cattle on feed in 23 states	Thous. Head
COF39(X)	January 1 cattle on feed in 39 states	Thous. Head

TABLE I (Continued)

Variable Name	Description	Units
COWS	Commercial slaughter of cows	Thous. Head
COWSMA	Moving average of quarterly cow slaughter $[(COWS_{t-1} + COWS_{t-2} + COWS_{t-3} + COWS_{t-4}) \div 4.0]$	
CPI(X)	Consumer price index (1967 = 100.0)	
CPRLRD	Difference in crop year corn price (t-1) and loan rate for year t; minimum value = 0.0 (deflated)	$/bu.
CPROD	Annual corn production	Mil. Tons
CPUI	Index of animal units being fed based on average feed requirements $[.333 * MCAS + 1.0 * BPRD + .763 * COF_{t-1} + .1715\ (MHI_{t-1} + BHI_{t-1})]$	
CRNP	Average corn price received by farmers in hundred weight (CRNPB ÷ .56)	$/cwt.
CRNPB	Average corn price received by farmers in bushels (.56 * CRNP)	$/bu.
CRNPLR	CRNP - Corn Loan Rate (Maximum value = $.30)	$/cwt.
CRNPMA	Weighted moving average of corn price $(= .2 * CRNP_t + .3 * CRNP_{t-1}$ $.5 * CRNP_{t-2})$	$/bu.
CTEFSD(X)	Cotton effective support rate (deflated)	¢/lb.
CTPRLRD(X)	Difference in crop year cotton price (t-1) and loan rate for year t; minimum value = 0.0 (deflated)	¢/lb.
CYLD	Corn average yield per acre	Cwt./acre
D1(X)	Intercept dummy (= 1 in first quarter, = 0, otherwise)	

TABLE I (Continued)

Variable Name	Description	Units
D2(X)	Intercept dummy (= 1 in first quarter, = 0, otherwise)	
D3(X)	Intercept dummy (= 1 in first quarter, = 0, otherwise)	
D4(X)	Intercept dummy (= 1 in first quarter, = 0, otherwise)	
DCI	Dairy cow inventory (January 1)	Thous. Head
DCORN(X)	Dummy variable to reflect the change in calculation of effective support rate (= 1 in 1966 to present; = 0 otherwise)	
DGS(X)	Dummy variable to reflect period in which wheat diverted acres could be planted to grain sorghum (= 1 in 1956-1961; = 0 otherwise)	
DGSWPA(X)	DGS * Wheat planted acres	Mil. Acres
DUM73(X)	Dummy variable accounting for effects of government price freeze (= 1 in 3rd and 4th quarters of 1973, 1974, and 1st quarter of 1975; = 0 otherwise)	
EXCH(X)	Weighted exchange rate in terms of foreign currency per dollar; weights based on average U. S. feed grain imports (Belg.-Lux. = 5.6%; Germany = 12.0%; Italy = 12.4%; Netherlands = 22.0%, United Kingdom = 11.4%; Japan = 36.6%; 1962 = 1.0)	
FBEEF	Total production of fed beef	Mil. lbs.
FBEEFPC	Fed beef supplies per capita	Lbs.
FEDMKTG	Fed cattle marketings in 39 states	Thous. Head
FEDW	Average dressed slaughter weight of fed steers and heifers	Lbs.

TABLE I (Continued)

Variable Name	Description	Units
FGCSTK	Commercially owned ending feed grain stocks	Mil. Tons
FGDOM	Food, seed, and industry domestic demand for feed grains	Mil. Tons
FGFEED	Domestic demand for feed grains as livestock feed	Mil. Tons
FGGSTK	Government owned ending feed grain stocks	Mil. Tons
FGPROD	Annual feed grain production	Mil. Tons
FMKTG23	Fed cattle marketings in 23 states	Thous. Head
FSP	Average price of good and choice feeder steers in 8 principal markets	$/cwt.
GR1	Average growth rate for market hogs greater than 180 lbs.	Lbs./day
GR2	Average growth rate for market hogs, 120-179 lbs.	Lbs./day
GR3	Average growth rate for market hogs, 60-119 lbs.	Lbs./day
GR4	Average growth rate for market hogs less than 60 lbs.	Lbs./day
GSEDVD(X)	Grain sorghum effective diversion payment (deflated)	$/bu.
GSEFSD(X)	Grain sorghum effective support rate (deflated)	$/bu.
GSHA	Grain sorghum harvested acres	Mil. Acres
GSPR	Average grain sorghum price received by farmers	$/bu.
GSPRLRD	Difference in crop year grain sorghum price (t-1) and loan rate for year t; minimum value = 0.0 (deflated)	$/bu.

TABLE I (Continued)

Variable Name	Description	Units
GSPROD	Annual grain sorghum production	Mil. Tons
GSYLD	Grain sorghum average yield per acre	Cwt./acre
INCEJK(X)	Per capita income index of EC-6 countries, Japan and United Kingdom. Weights are same as used for EXCH. (1962 = 1.0)	
HOGWGT	Average dressed weight of all hogs slaughtered commercially	Lbs.
MCAS	Milk cow inventory adjusted quarterly based on seasonal production patterns (1st = .978; 2nd = 1.099; 3rd = .991; 4th = .932)	Thous. Head
MPC (X)	Annual average milk production per cow	Lbs.
MPW (X)	Average wage paid in the meat packing industry	$/hour
MPWR (X)	Residuals of regressing MPW on trend	$/hour
NCCROP	Annual calf crop less calf deaths	Thous. Head
NFBEEF	Domestic production of non-fed beef	Mil. Lbs.
NFBFS	Domestic supplies of non-fed beef (NFBEEF + BIMP - BEXP)	Mil. Lbs
NFBFSPC	Domestic supplies of non-fed beef per capita	Lbs.
NFEDW	Average dressed slaughter weight of non-fed cattle	Lbs.
NFSHS	Non-fed steer and heifer slaughter	Thous. Head
OEFSD (X)	Oats effective support rate (deflated)	$/bu.
OHA	Annual oats harvested acres	Mil. Acres
OPR	Average oats price received by farmers	$/bu.

TABLE I (Continued)

Variable Name	Description	Units
OPROD	Annual oat production	Mil. Tons
OYLD	Average oat yield per acre	Cwt./acre
PBG	Average price of barrows and gilts at seven principal markets	$/cwt.
PBGIX	PBG_t ÷ Average PBG, 1955-1964	
PBYPRD (X)	Value of edible and inedible by-products of pork processing	$/cwt.
PCON (X)	Index of pasture and range conditions	
PDW (X)	Average wage paid in poultry dressing industry	$/hour
PEXP (X)	Pork exports and shipments out of U. S.	Mil. Bu.
PIGC	Quarterly pig crop	Thous. Head
PIMP (X)	Pork imports for the U. S.	Mil. Lbs.
PORK	Commercial pork production in U. S.	Mil. Lbs.
PORKS	Domestic pork supply available	Mil. Lbs.
PORKSPC	Domestic pork supply per capita	Lbs.
PPD (X)	Index of prices paid by farmers for production inputs	
PROF	Feeder steer price (FSP) divided by cost of raising calves (see footnote on page 65)	$/cwt.
REPL	Pigs used as replacements for breeding hog inventory	Thous. Head
ROWD	Annual coarse grain utilization in the world less U. S. feed grain utilization	Mil. Tons
ROWP	Annual coarse grain production in the world less U. S. feed grain production	Mil. Tons

TABLE I (Continued)

Variable Name	Description	Units
RPCDI (X)	Average personal disposable income in the U. S. deflated by CPI	$
SABD	Deaths in breeding hog inventory (sows and boars)	Thous. Head
SABS	Commercial sow and boar slaughter	Thous. Head
SBLRD (X)	Soybean loan rate (deflated)	$/bu.
SBPRLRD (X)	Difference in crop year soybean price (t-1) and loan rate for year t; minimum value = 0.0 (deflated)	$/bu.
SBMP (X)	Price of soybean meal (Decatur, 44% protein)	$/ton
SBMPMA (X)	Weighted moving average of soybean meal price (= .2 * $SBMP_t$ + .3 * $SBMP_{t-1}$ + .5 * $SBMP_{t-2}$)	$/ton
SSP	Price of choice slaughter steers in Omaha market	$/cwt.
SSPIX	SSP_t ÷ Average SSP, 1955-1964	
T (X)	Annual linear time trend variable (= 1 in 1950, = 27 in 1976)	
TIME (X)	Annual linear time trend variable (= 1 in 1958, = 19 in 1976)	
TOTDA (X)	Total acreage diverted from feed grain production under government programs	Mil. Acres
TOTPL	Placements of cattle on feed in 23 states	Thous. Head
TQ (X)	Quarterly linear time trend variable (= 1 in 1st quarter of 1950, = 108 in 4th quarter of 1976)	
UCBP	Wholesale price of utility cow beef	$/cwt.
UCP	Price of utility grade cows in Omaha market	$/cwt.

TABLE I (Continued)

Variable Name	Description	Units
WBP	Wholesale broiler price (nine city average)	\$/cwt.
WEDVD (X)	Wheat effective diversion payment (deflated)	\$/bu.
WEFSD (X)	Wheat effective support rate (deflated)	\$/bu.
WPP	Wholesale price of pork cuts (Chicago)	\$/cwt.
WPRLRD (X)	Difference in crop year wheat price (t-1) and loan rate for year t; minimum value = 0.0 (deflated)	\$/bu.

production for each crop is specified as a multiplicative function of harvested acres and yield per acre.

Specification of Acreage Equations

Annual acreage equations have been estimated for major field crops in several recent studies (9) (19) (46). Houck and Ryan (8) in 1972 introduced the concepts of "effective support rate" and "effective diversion payment rate" as a means of combining government acreage restrictions with announced government payments into a single variable. The general formula for the calculation of the effective support rate may be expressed as:

$$\text{Effective support rate} = (r) * \text{Announced support rate},$$

where r is a coefficient ranging from 0.0 to 1.0 and lying closer to 0.0 when government programs are more restrictive on planted acreage allowed. The r coefficient is unknown and cannot be statistically estimated, but an r consistent with the restrictions on crop acreage for each announced support rate can be developed. The method employed by Houck and Ryan is to make r a linear function of acreage restrictions. Thus, if producers are required to leave 20 percent of assigned base acreage out of production to qualify for the announced support rate, r equals .80.

The effective diversion payment rate is similarly derived by the general formuls:

$$\begin{array}{l}\text{Effective diversion}\\ \text{payment rate}\end{array} = (w) * \begin{array}{l}\text{Announced diversion}\\ \text{payment}\end{array}$$

The w coefficient also ranges between 0.0 and 1.0, lying closer to 1.0 as the percentage of base acreage qualifying for diversion payment increases.

The effective diversion payment rate is then hypothesized to be negatively related to crop acreage since higher diversion payments should induce farm operators to leave more land idle. The effective support rate as a conditioned price variable is hypothesized to be positively related to acreage response.

Specifications of acreage equations which include these two explanatory variables perform well over an estimation period of crop years prior to 1973, explaining a large proportion of the variation in acreage. In years following 1973, two developments in agricultural markets have created the need for revised specification. The prices paid for agricultural inputs have escalated to the extent that some consideration of production costs is necessary. Also, for the 1973-1976 interval market prices were high in relation to support levels offered by the government.

Considering the costs of agricultural inputs, two factors have been of primary importance over the period of estimation. Technological progress and improved production practices have contributed to increasing yields per acre. This phenomenon has tended to drive down the production cost per bushel. The prices paid for all agricultural inputs have caused the cost per acre harvested to increase. To account for both of these factors affecting the cost per unit of output, a variable was developed to be used as a deflator for all prices entering crop acreage equations.

The basis for each price deflator is the index of prices paid by farmers for production inputs. To calculate the specific deflator for each crop, this index is divided by a variable hypothesized to reflect expected yield for the crop. For example, the base year used for measurement of expected yields is 1956. Expected yield for years thereafter is expressed in terms relative to 1956 in the form: (Expected yield for year t) ÷ (Expected yield in 1956). This variable is then used in conjunction with the prices paid index to develop price deflators on a crop by crop basis of the form:

$$\frac{\text{Prices Paid by Farmers}}{\left(\dfrac{\text{Expected Yield in Year t}}{\text{Expected Yield in 1956}}\right)}$$

This form of deflator for supply response prices assumes per acre cost changes to be reflected by the prices paid index. The change in expected yields, representing a measure of productivity per acre, is used to adjust changes in cost per acre to obtain an estimate of cost change per unit of output. Assuming that expectations are a function of previous experience, the application of this concept in this study used a moving average of yields in the three most recent years to represent expected yield per acre in year t.

To incorporate the influence of recent market price levels on acreage, a supply response concept which considers both market prices and loan rates in one variable was developed. The hypothesis underlying this variable is that producers do respond to high market prices received in past periods, but the response is not the same as for loan rates which are guaranteed by the government. Harvested acreage relations may then be specified as functionally related to the effective support rate and the amount that the previous year market price exceeds the current year guaranteed loan rate:

$$\text{Harvested Acres} = f[\text{Effective Support Rate} + g(\text{Market Price}_{t-1} - \text{Loan Rate})] + \ldots$$

The supposition is that market prices have no influence if below the loan rate. Thus, a minimum value of zero is placed on the difference: Market Price_{t-1} - Loan Rate.

The four acreage equations were specified as being functions of own price variables and price variables for competing crops. Each price variable was used in deflated form. Variables which had estimated coefficient signs in violation of hypothesized relations were rejected and not included in the final estimated form. The four annual equations were estimated as a system using the seemingly unrelated regression technique (11). Although ordinary least squares would lead to unbiased and consistent estimators, this procedure improves the efficiency of estimation when the disturbances across equations are correlated. The estimation period includes the crop years 1956 to 1976.

<u>Corn Harvested Acres</u>

The primary substitute crop for corn in the leading corn producing states is soybeans. In the corn equations both the support rate and the difference in lagged market price and support rate for soybeans (SBPRLRD, SBLRD) were included along with the own price variables for corn (CPRLRD, CEFSD). The coefficients on the soybean price variables reflect the strong competitive relation between these two crops. Other crops hypothesized to compete with corn were alternative feed grain crops and wheat. The coefficient for the effective support variable for grain sorghum (GSEFSD), although not significant at the five percent level, displays a competitive relationship. The negative sign on the parameter estimate for the effective diversion payment for wheat (WEDVD) indicates that larger diversion payments for wheat causes land to remain idle that might otherwise be used in corn production. The dummy variable (DCORN) is used to account for a change in government programs which necessitated a change in the way the effective support rate was calculated.[1] The pasture conditions index is intended to reflect the effect of weather on harvested acreage.[2] Some acreage planted may not be harvested for grain if the low yields caused by adverse weather make combine harvesting too costly.

$$
\begin{aligned}
CHA = 63.268 &+ \underset{(2.59)}{11.422}\ CEFSD + \underset{(1.38)}{2.320}\ CPRLRD - \underset{(7.12)}{30.132}\ CEDVD + \\
&\underset{(2.26)}{.159}\ PCON - \underset{(2.84)}{4.560}\ SBLRD - \underset{(4.44)}{5.245}\ SBPRLRD - \underset{(3.76)}{4.351}\ WEDVD - \\
&\underset{(.98)}{1.600}\ WEFSD - \underset{(1.94)}{4.450}\ GSEFSD + \underset{(3.81)}{4.40}\ DCORN
\end{aligned}
$$

$R^2 = .982 \qquad DW = 2.57$

---

[1] Program provisions in 1977 were changed to limit support payment to only 50 percent of base acreage. A separate payment for diverted acreage was also discontinued. Diversion was still required to qualify producers for support payment such that the payment offered functioned as a diversion payment rather than as a support payment. Therefore, support payments above loan rates offered in 1966 and following years were calculated as part of the effective diversion payment. The dummy variable allows for a possible change in response patterns of producers to revised program payment definitions.

[2] This index is a measure of growing conditions for pastures and ranges in the U. S. Although a weather index more specific to particular geographic regions would be more desirable, this variable apparently provides some information regarding the weather influence on harvested acreage and output of the four crops considered.

Grain Sorghum Harvested Acres

Although grain sorghum production in the U. S. is small in relation to corn, it is grown in some regions where corn is not a major crop. Because of its resistence to dry weather, grain sorghum is an important crop in the southern and western plains, where it competes with cotton and wheat for tillable land.

$$\begin{aligned} GSHA = {} & .653 + \underset{(2.07)}{2.586}\ GSEFSD + \underset{(1.59)}{2.782}\ GSPRLRD - \underset{(1.45)}{6.199}\ GSEDVD + \\ & \underset{(2.01)}{2.039}\ DCORN + \underset{(2.47)}{.170}\ PCON + \underset{(5.85)}{41.368}\ DGS - \underset{(6.46)}{.718}\ DGSWPA - \\ & \underset{(2.82)}{.130}\ CTEFSD - \underset{(1.55)}{.114}\ CTPRLRD - \underset{(.45)}{.331}\ SBPRLRD - \underset{(1.04)}{3.231}\ CPRLRD - \\ & \underset{(.13)}{.095}\ WPRLRD \end{aligned}$$

$R^2 = .944 \qquad DW = 1.82$

Resembling the corn equation, the grain sorghum harvested acreage equation includes the effective support, effective diversion payment and a variable reflecting the influence of past grain sorghum market prices. The same dummy variable used in the corn equation to account for the change in calculation of the effective support rate variable is also used in this equation for the same purpose. The dummy variable, DGS and DGSWPA, represent a change in government programs in 1962. In 1962, a program which allowed diverted wheat acreage to be planted to grain sorghum was abandoned. Therefore, in the years before 1962, the number of acres planted in wheat had a stronger impact on grain sorghum acreage. The lagged market price variables for cotton, soybeans, corn and wheat and effective support for cotton are contained in the equation even though the t-values indicate little statistical significance. The coefficient signs do lend some support to the substitutability between these crops and grain sorghum. The overall fit of the equation indicated by the R^2 is acceptable and the reported Durbin-Watson statistic is within the range signifying no significant autocorrelation in the residuals.

Barley Harvested Acres

Barley is grown primarily in the northern plains and is not closely competitive with other feed grains for available tillable land. The estimated equation for barley harvested acreage contains own price variables, the pasture conditions index, a time trend variable and three substitute crop price variables. According to relative coefficient magnitudes, wheat appears to be the principal substitute crop for barley. The coefficient for the pasture conditions index is statistically significant and the positive sign reflects the increase in harvested acreage due to improved weather conditions. The sign on the linear trend variable signifies the declining importance of barley in the total production of animal feeds.

$$
\begin{aligned}
BHA = 9.121 &+ \underset{(1.34)}{1.446}\ BEFSD + \underset{(.78)}{1.639}\ BPRLRD - \underset{(2.95)}{6.652}\ BEDVD + \underset{(2.47)}{.121}\ PCON \\
&- \underset{(1.68)}{.144}\ T - \underset{(2.72)}{2.909}\ WEFSD - \underset{(.99)}{1.591}\ CPRLRD - \underset{(.81)}{.700}\ SBPRLRD
\end{aligned}
$$

$R^2 = .912 \qquad DW = 2.20$

Oats Harvested Acres

Harvested acreage of oats over the sample period, 1956-1976, has declined substantially. Government programs may have induced some of this phasing out of oats, but the increase in yield per acre for oats has not kept pace with that for other feed grain crops.

$$\underset{}{OHA} = 41.127 + \underset{(1.08)}{7.391}\ OEFSD + \underset{(1.81)}{.188}\ PCON - \underset{(5.97)}{3.875}\ T + \underset{(4.51)}{.0901}\ T^2$$

$$- \underset{(.43)}{1.038}\ CEFSD - \underset{(.38)}{.857}\ BPRLRD - \underset{(.50)}{.620}\ SBPRLRD - \underset{(.63)}{1.444}\ WEFSD$$

$$R^2 = .988 \qquad DW = 1.82$$

Included in the estimated equation for oats acreage are an own price variable, the pasture conditions index and four price variables for substitute crops. None of the coefficients on competing crop price variables is significant, but all are retained as signs support theoretical expectations. The linear and quadratic trend variables are the most significant variables and together explain most of the variation in the dependent variable. The R^2 indicates that little variation in the dependent variable is left unexplained by the independent regressors.

<u>Yields of Feed Grain Crops</u>

The yield per acre for all the feed grains has increased substantially since the 1950's. This phenomenon is the combined result of improved varieties and better farming practices. The sample period of estimation for yield relationships was chosen on the basis of historical trends. In a few years prior to 1955 yield increases were very dramatic. Since 1955 the growth in yields has been accomplished at a fairly steady pace. Therefore, the estimation period for yield equations covers the 1955-1976 time interval. All the yields are expressed in hundredweight per acre to facilitate combining units into a feed grain production quantity.

Corn Yield Per Acre

The estimated equation for corn yield per acre contains four explanatory variables. The trend variable is very significant and depicts a stable growth in yields over the estimation period. The pasture conditions index, positively related to yields, provides a proxy for the influence of weather conditions on production. The effective support rate variable indicates an improvement in yields as the crop becomes more valuable. The coefficient for total acreage diverted from feed grain production (TOTDA) also carries a positive sign. This supports the hypothesis that producers tend to divert marginally productive land, increasing the overall average yields.

$$\begin{aligned} \text{CYLD} = -13.365 &+ \underset{(9.36)}{1.086}\ \text{T} + \underset{(1.78)}{.294}\ \text{PCON} + \underset{(1.54)}{6.722}\ \text{CEFSD} + \underset{(3.27)}{.144}\ \text{TOTDA} \end{aligned}$$

$R^2 = .910 \qquad DW = 2.41$

Grain Sorghum Yield Per Acre

The grain sorghum yield equation contains a set of variable similar to the corn yield equation. The coefficients all carry the expected signs but the difference in relative magnitudes for the corn and grain sorghum equations is interesting. The trend in increased grain sorghum yield has been more gradual than that for corn. Also, the pasture conditions index is larger and more significant for grain sorghum. This is probably caused by the regional distribution of acreages. A large proportion of grain sorghum acreage is in the southern and western states and these states make up the majority of the sample used in constructing the pasture index. Therefore, this index is likely a better indicator of the weather situation affecting grain sorghum yields.

$$\begin{aligned}\text{GSYLD} = -24.218 &+ .533\ \text{T} + .394\ \text{PCON} + 4.191\ \text{GSEFSD} + .155\ \text{TOTDA}\\ &\quad\ (5.73) \qquad (3.91) \qquad\quad (2.07) \qquad\qquad (5.69)\end{aligned}$$

$R^2 = .925 \qquad DW = 1.69$

Barley Yield Per Acre

In estimating the yield equation for barley, the pasture conditions index was tested but rejected based on its estimated negative coefficient. As shown by the trend variable coefficient, barley yield has also been increasing but at a slower pace than corn and grain sorghum.

$$\begin{aligned}\text{BYLD} = 10.697 &+ .365\ \text{T} + .278\ \text{BEFSD} + .061\ \text{TOTDA}\\ &\quad\ (8.77) \qquad (.20) \qquad\quad (3.60)\end{aligned}$$

$R^2 = .861 \qquad DW = 1.99$

Oats Yield Per Acre

The structure of the yield equation for oats strongly resembles that for the other feed grain equations. Total acreage diverted is not part of the estimated form reported as its coefficient was inconsistent with the hypothesized relationship with yield. Of the four crop yield relations the oats equation has the poorest fit.

$$\begin{aligned}\text{OYLD} = -4.626 &+ .239\ \text{T} + .139\ \text{PCON} + 6.136\ \text{OEFSD}\\ &\quad\ (8.11) \qquad (3.26) \qquad\quad (4.37)\end{aligned}$$

$R^2 = .821 \qquad DW = 2.58$

Feed Grain Production

The projection equation for the total production of each feed grain is simply the product of harvested acreage and the yield per harvested acre. As a matter of unit conversion, the total production is divided by a factor of 20 to convert million hundredweight to million tons of production.

$$CPROD = (CHA * CYLD) \div 20.0$$

$$GSPROD = (GSHA * GSYLD) \div 20.0$$

$$BPROD = (BHA * BYLD) \div 20.0$$

$$OPROD = (OHA * OYLD) \div 20.0$$

$$FGPROD = CPROD + GSPROD + BPROD + OPROD$$

Feed Grain Demand

The production of feed grains is assumed to be predetermined for each crop year. Supply of feed grains on a quarterly basis is also hypothesized to be predetermined and equal to the stocks held at the beginning of the quarter plus the production occurring within the quarter. Quarterly price and demands for feed grains are specified as a simultaneous system whereby an equilibrium price is determined which satisfies the demand for each use.

U. S. feed grain utilization may be divided into five segments: domestic feed demand for livestock, other domestic demand (seed, food and industry), export demand, commercial stock demand and government stock demand. Domestic livestock feed is the major end use demand for feed grains, but export demand has displayed substantial growth throughout the estimation period.

Other Domestic Demand

Domestic demand of feed grains for seed, food and industrial purposes has exhibited a stable quarterly pattern over the estimation period of 1963 to 1976. Grains consumed by humans and industry have been fairly constant with a quarterly pattern caused mainly by the difference in length of feed grain quarters. As noted previously, feed grain quarters follow the familiar calendar quarter basis with the exception that June is deleted from the April-June quarter and added to the July-September quarter. The quarterly demand for seed is heaviest during the January-March and April-May periods when most crop planting takes place.

$$\underset{}{FGDOM} = .188 + \underset{(6.33)}{.00123}\ RPCDI - \underset{(4.81)}{.289}\ D2 + \underset{(16.27)}{1.114}\ D3 - \underset{(4.68)}{.286}\ D4$$

$$R^2 = .928 \qquad \underset{(3.51)}{\rho = .467} \qquad DW = 2.11$$

The quarterly domestic demand for food, seed and industry was hypothesized to be a function of the price of feed grains, population, disposable personal income, projected harvested acreage for the next year and quarterly dummies to adjust for seasonality in utilization. In estimating the equation, the coefficients for price of feed grains, population and projected acreage all carried signs which were in disagreement with hypothesized relations and were dropped from the specification. The estimated form of the equation is solely a function of personal disposable income and seasonal dummies. Since this specification is not functionally related to price, it is considered predetermined for the quarter and is not included with the simultaneous set of demand relationships. Ordinary least squares estimation yielded a Durbin-Watson statistic indicating autocorrelated disturbances. The reported final form of the relation was estimated with the autoregressive least squares technique suggested by Martin and Fuller (5). The overall fit of the equation is good and the reported Durbin-Watson demonstrates the problem with the error structure to be corrected. The first order autocorrelation coefficient is also shown to be significantly different from zero by its reported t-value.

Demand for Livestock Feed

Feed grain demand for feed is derived as an input demand from the domestic production of livestock. Therefore, this demand is related to both the number of livestock units being fed and the value of those livestock units. Other factors considered important in determining the level of feed demand are the price of substitute feeds and the seasonality of demand.

$$
\begin{aligned}
FGFEED = {} & 15.609 - \underset{(2.29)}{2.223}\,(CRNPMA_t) - \underset{(4.37)}{2.700}\,(D3 * CRNPMA_t) \\
& + \underset{(1.40)}{.000285}\,(CPUI_t) + \underset{(4.03)}{.000755}\,(D4 * CPUI_t) + \underset{(1.66)}{4.173}\,(APIX_{t-2}) \\
& + \underset{(1.50)}{.0246}\,(SBMPMA_t) - \underset{(20.50)}{17.184}\,(D2) + \underset{(3.37)}{64.33}\,(D3) - \underset{(2.41)}{9.880}\,(D4)
\end{aligned}
$$

$$
R^2 = .946 \qquad \rho = \underset{(2.99)}{.446} \qquad DW = 1.86
$$

In the set of feed grain demand relationships, corn price is used as a proxy for the price of feed grains. One reason for this is that no acceptable quarterly price series for feed grains as an aggregate was found. Corn price was chosen in lieu of the prices for other feed grains, because corn production far exceeds that of the other grains. In estimating the feed demand equation, the price of corn in both current period and lagged forms was found to be related to feed demand. This result is not surprising given that most livestock feeders carry some stocks of grain for future feeding and may have future agreements to purchase grain. The use of a variable and lagged forms of the same variable in an equation, however, often creates a problem of multi-collinearity among explanatory variables. To avoid this situation a weighted moving average of current and past corn prices was used. Several weighting schemes which could be justified from an economic standpoint were tested. The final form for the variable was chosen on the basis of its explanatory power over the observation period.

A variable to represent the number of livestock units being fed was chosen on the basis of the types of livestock included in the model. The livestock categories endogenous to the overall model and which consume large amounts of feed grains are dairy cows, hogs, broiler chickens and cattle on feed. An animal unit index, CPUI, was constructed for these four categories on the basis of average annual consumption per animal production unit of feed grains over the 1965 to 1975 period (40). The calculated weights used for each animal group are displayed in the definition of the variable in Table I.

A livestock price index, APIX, was also constructed to represent the value of livestock being fed. The price series endogenous to the model which were chosen for index construction are the price of slaughter steers, the price of barrows and gilts and the farm price of broiler chickens. Weights for the price index are based on the average total utilization of feed grains by each livestock category during the 1965 to 1975 period.

The estimated form of the feed demand equation includes a continuous corn price variable and a dummy corn price variable which allows the nature of the relationship to shift during the third quarter. The third quarter is the June-September period in this case, and the negative coefficient on the dummy variable indicates that as the length of the period increases, the quantity adjustment to a given price change is larger.

The animal unit index is also contained in the equation in continuous and dummy forms. The large coefficient on the dummy variable is probably due to the seasonality of cattle feeding. A large number of cattle are placed on feed during the fall and the animal units index intended as a proxy for all animal units being fed is actually heavily weighted toward the number of cattle on feed.

The price index for animal units is lagged two periods, suggesting that animal values have more impact on planning decisions for future feeding than for current quarter demand. The soybean meal price coefficent has a positive sign denoting its substitutability for feed grains in animal rations. The same form of weighted moving average used for corn price was applied to this variable, the hypothesis being that planning and feeding decisions are based on past and current comparisons of substitute prices.

The equation reported was estimated by autoregressive two-stage least squares. The endogenous explanatory variable, corn price, was first regressed on the set of explanatory variables for the system and a one period lag of the same variables using ordinary least squares. In the second stage the structural equation was estimated by autoregressive least squares. As shown by its t-value, the first order autocorrelation parameter is significant.

Government Stock Demand

Stocks of feed grains may be held by either the government or private sector. The government accumulates grain under its government support operations whenever market price falls to a level near the loan rate. Producers are allowed to place grain in storage and use the grain as collateral for a loan. If market prices do not improve over the life of the loan, producers may choose to transfer ownership of the grain to the government in meeting the loan obligation. Also, when market prices are heavily depressed by large supplies of grain, the government can make direct market purchases of feed grains. This alleviates some of the downward pressure on price but causes government stocks to grow.

$$FGGSTK = -.466 - \underset{(1.45)}{2.739}\, CRNPLR_t + \underset{(39.47)}{.9532}\, FGGSTK_{t-1} + \underset{(1.68)}{1.309}\, D2$$

$$+ \underset{(1.70)}{1.328}\, D3 + \underset{(1.40)}{1.089}\, D4$$

$$R^2 = .974 \qquad DW = 1.36$$

The estimated relationship for government stocks contains a lagged dependent variable. This form of equation attempts to model an adjustment process which can only be partially completed within the period of observation. The coefficient on lagged government stocks is close to unity, implying the proportion of desired adjustment made within a quarter is relatively small.

Also included in the government stock equation is the variable CRNPLR which represents the relative magnitudes of the market price for corn and the loan rate by the absolute difference in values. In the variable definition the difference (corn price - loan rate) is set at a maximium of $.30. By doing so, the stock adjustments when the difference exceeds this value is fixed at a constant rate per quarter. Several maximum values for the variable above and below and $.30 level were tested. The level chosen was based on relative explanatory powers and the statistical significance of each variable.

The equations was estimated by two stage least squares. Although the Durbin-Watson statistic suggests a problem with autocorrelated errors, the use of autoregressive least squares for the second stage of estimation yielded an insignificant first order autocorrelation coefficent.

Commercial Stock Demand

Commercial stocks of feed grains are held by several different market participants for various reasons. Producers may store grain to take advantage of price rises following harvest. Producers may also hold grain for planting seed or for use in livestock production on the farm. Millers and processors hold grain to insure a ready input supply and to guard against unforeseen market fluctuations.

$$
\begin{aligned}
FGCSTK = {} & \underset{(31.71)}{9.066 + .685} \,(FGPROD_t + FGCSTK_{t-1}) - \underset{(8.09)}{3.55}\, CRNP_t \\
& + \underset{(1.71)}{1.247}\,(D3 * CRNP_t) + \underset{(1.85)}{1.274}\,(D4 * CRNP_t) + \underset{(3.24)}{4.480}\, D2 \\
& - \underset{(9.26)}{22.605}\, D3 + \underset{(3.01)}{6.584}\, D4
\end{aligned}
$$

$R^2 = .997 \qquad DW = 1.786$

The commercial stock equation is specified in a form depicting stocks as a residual claimant on supplies. The variable, ($FGPROD_t$ + $FGCSTK_{t-1}$), represents the commercial supply of feed grains and its use in the equation is logical given that grain not consumed during a quarter must be stored for following quarters. The price of corn in the equation carries a negative sign which indicates the willingness of stock holders to release grain from storage as price increases. Dummy variables for the third and fourth quarter on corn price allow the stock response to price to change during those quarters. The positive coefficients for the two dummy variables are evidence that the stock adjustments to price change declines in the third and fourth quarters.

Export Demand for Feed Grains

The export demand for U. S. feed grains is primarily determined by world supply and demand conditions. As average incomes have increased in the rest of the world, meat consumption has grown and caused the demand for feed grains an an input for livestock production to rise. U. S. agriculture normally produces a quantity of feed grains in excess of domestic needs and maintains a large stock reserve relative to other producing countries in the world. Therefore, the U. S. may be viewed as a residual supplier to the world market. If a shortfall in production occurs for the rest of the world, the exports of grain from the U. S. may be expected to largely make up the difference in world quantities demanded and supplied.

Given a role of residual supplier, the export demand function for the U. S. feed grain market is specified to be related to the excess demand in the rest of the world. The excess demand relationship is derived by separately estimating feed grain supply and demand for the rest of the world. When providing an estimate for both supply and demand for feed grains for other countries, data considerations become important. World data lumps feed grains into a classification called coarse grains which includes rye and millet in addition to the other feed grains. Also, quarterly data on coarse grain production and consumption is not available so that the period of observation must be annual.

As an estimate of world supply, a relationship for annual non-U. S. coarse grain production was developed. Growth in the production of coarse grains has been fairly steady over the estimation period of 1963-1976 and was specified to be a linear function of time. To relate supply response to market conditions, a lagged corn price was tested in the equation but proved to be unsuccessful in explaining variation in production. Weather is probably the overriding influence in non-U. S. coarse grain output and is assumed to be retained in the random disturbance term for the equation. The relationship was estimated with ordinary least squares and the R^2 demonstrates that a strong trend exists in non-U. S. production.

$$\text{ROWP} = 179.867 + \underset{(13.88)}{13.321}\ \text{TIME}$$

$$R^2 = .941 \qquad \text{DW} = 2.85$$

Demand for coarse grains in the rest of the world, although available only on an annual basis, was estimated in quarterly form to allow consumption to respond to a quarterly price. The dependent variable for each quarter is simply the reported annual figure for the year. Explanatory variables included in the equation are the animal units on hand in a sample of foreign countries and a personal income index for those same countries. The countries in the representative sample traditionally are heavy importers of U. S. feed grains and include the EC-6 countries plus Japan and the United Kingdom. Animal units as defined consist of cattle and hogs, and according to approximate grain consumption levels, the hog inventory is assumed to represent only two-fifths of the potential grain demand of the cattle inventory. The weights used for the income index were calculated from the proportion of total U. S. feed grain exports represented by each country's imports over the 1963-1976 period.

$$\text{ROWD} = -35.527 - \underset{(2.86)}{7.401}\ \text{CRNP}_t + \underset{(5.66)}{.00626}\ \text{ANUNIT}_t + \underset{(5.51)}{.2803}\ \text{INCEJK}_t$$

$$R^2 = .989 \qquad \rho = \underset{(7.15)}{.772} \qquad \text{DW} = 1.36$$

The price of corn in the U. S. is contained in the equation to represent the level of feed grain price in the world. Although this variable does not fully account for variation in the purchase price for grain for each country, the free markets in the U. S. cause the average world, and U. S. prices to be highly correlated.

The equation for coarse grain demand in the rest of the world was estimated with autoregressive two-stage least squares. Corn price is significant at the five percent level and displays the sign supported by economic theory. The number of animal units and income are both significant as explanatory variables and as expected are positively related to grain consumption.

Feed grain exports from the U. S. are assumed to be largely determined by the difference in production and consumption in the rest of the world. In reality, the market prices in the U. S. relative to the market prices in other grain exporting countries also has some bearing on the level of the U. S. exports. However, attempts to model this factor into the export demand relationship were unsuccessful.

$$FGEXP = 2.408 + \underset{(9.03)}{.2196} (ROWD_t - ROWP_t) - \underset{(.32)}{1.515} EXCH - \underset{(4.00)}{2.546} D2$$

$$+ \underset{(4.30)}{2.646} D3 + \underset{(.95)}{.595} D4$$

$$R^2 = .840 \qquad DW = 1.56$$

Another factor which affects exports are the currency values of importers and exporters. As the value of the U.S. dollar declines relative to the currencies of importing countries, the import price paid also declines. An index of the exchange rate of foreign currencies for the dollar was developed to account for this factor. Weights used for the index (EXCH) are based on the average imports of U. S. grains by country over the 1969-1976 period.

The equation for U. S. feed grain exports was estimated with two-stage least squares. Dummy variables were included along with the continuous regressors to account for the seasonality in export demand

and the difference in time intervals within each quarter. As expected, the most significant explanatory variable is the proxy variable for excess demand in the rest of the world.

Supply Demand Identity

The feed grain model is completed by the addition of an identity relationship restricting the sum of quarterly demands to be equal to supply. Through this relationship the quarterly price becomes endogenous to the system and behaves as a rationing device to satisfy all the demand components for feed grains subject to available supplies.

$$FGDOM_t + FGFEED_t + FGGSTK_t + FGCSTK_t + FGEXP_t = FGPROD_t + FGGSTK_{t-1} + FGCSTK_{t-1}$$

Other Feed Grain Price Equations

In the modeling framework for this research, the prices for all the feed grains must be determined endogenously to be able to project the production levels for each grain the following year. Therefore, price equations linking the quarterly prices for grain sorghum, barley and oats to the corn price determined by the interaction of demand and supply in the feed grain market were developed.

The relationships between the prices for each feed grain are presumed to be fairly stable. Prices may vary seasonally depending on the differences in harvest times. Average prices received for the different feed grains may also be affected by the level of production of each grain relative to total production.

$$GSPR_t = .0953 - \underset{(1.84)}{2.742}\ (GSPROD_t \div FGPROD_t) + \underset{(2.42)}{.00334}\ TQ + \underset{(24.55)}{.8141}\ CRNPB_t$$

$$- \underset{(.31)}{.0034}\ (D3 * CRNPB_t) + \underset{(3.31)}{.0375}\ (D4 * CRNPB_t)$$

$$R^2 = .990 \qquad \rho = \underset{(2.58)}{.406} \qquad DW = 1.79$$

$$BPR_t = .090 - \underset{(2.71)}{6.065}\ (BPROD_t \div FGPROD_t) + \underset{(24.30)}{.9331}\ CRNPB_t$$

$$- \underset{(4.81)}{.0532}\ (D3 * CRNPB_t) + \underset{(3.11)}{.0346}\ (D4 + CRNPB_t)$$

$$R^2 = .990 \qquad \rho = \underset{(6.05)}{.660} \qquad DW = 1.73$$

$$(OPR_t - OPR_{t-1}) = -.0025 - \underset{(2.53)}{1.755} \left(\frac{OPROD_t}{FGPROD_t} - \frac{OPROD_{t-1}}{FGPROD_{t-1}}\right)$$

$$+ \underset{(16.11)}{.3814}\ (CRNPB_t - \ RNPB_{t-1})$$

$$- \underset{(3.25)}{.0912}\ (D3_t * CRNPB_t - D3_{t-1} * CRNPB_{t-1})$$

$$+ \underset{(7.09)}{.0393}\ (D4_t * CRNPB_t - D4_{t-1} * CRNPB_{t-1}$$

$$R^2 = .856 \qquad DW = 1.79$$

The equations reported for barley and sorghum price were estimated with autoregressive least squares. The oats equation was also estimated with ALS but the first order autocorrelation coefficient obtained was almost unity. The reported oats equation was estimated with ordinary least squares in first difference form which assumes a first order autocorrelation coefficient of one.

The statistical fits of the price equations are generally high. As displayed by the dummy variables for corn prices, seasonal variation among the price for feed grains does exist and appears to depend primarily on harvesting periods.

Hog Production

The hog subsector of the model is comprised of a set of technical and behavioral relationships describing the production process from breeding hog inventories and pig crops through quarterly slaughter of hogs. The principal component of the model is the market hog sector which estimates the parameters controlling the flow of the pig crop through the various weight categories to a final output of commercial barrow and gilt slaughter. The modeling approach for this segment of the model is an application of continuous delay modeling and optimal control theory which were discussed in Chapter II.

Market Hog Model

Data for market hog inventories are reported quarterly and classify hogs into five weight categories: less than 60, 60 to 119, 120 to 179, 180 to 220, and greater than 220. For this model the latter two weight categories were combined to form four categories of approximately equal weight intervals (live slaughter wieghts generally range from 230 to 250). The market hog model attempts to simulate the flow of hogs from the pig crop, through the weight categories each quarter to slaughter, the end product.

The simulation model divides the quarter into 45 separate time segments, each approximately two days in length. An estimate of the monthly pig crop when fed into the model is allowed to enter market hog inventories in two day increments at a level equivalent to one-fifteenth of the total monthly estimate. As hogs enter the model and go into market hog inventories, other hog inventories pass through the model to heavier weight classes. Hogs which exceed the estimate for average ending weight are counted as hog slaughter within the model.

As was mentioned in Chapter II, the continuous delay modeling technique used in this simulation allows individual units within the flow to grow at various rates. Because no reliable data were found on the variance of growth rates among hogs, parameters for the delay processes were chosen so as to yield an output flow with a fairly symmetrical bell-shaped distribution. While the model simulates the animal growth functions, it also keeps track of outflow of slaughter animals, attrition by weight and hog inventories by weight for each two day time interval. Thus, an estimate of monthly hog slaughter can be obtained through the model by summing across proper time increments.

To operate the simulation model, several data requirements must be met. An estimate of the pig crop for each month of the quarter is necessary. The beginning inventories of market hogs by weight category must also be known or estimated. Finally, an estimate of the average ending weight must be available to determine the point in the growth process at which hogs are slaughtered. In addition, several parameters must be provided for the model to function properly. The average growth rate for each weight group must be known to provide the model with an estimate of the average delay time required for hogs to move through each weight class. The attrition rate for each weight group must also be known for the model to simulate the leakage occurring in the process.

Data for pig crops, inventories, slaughter weights and barrow and gilt slaughter are available from published data sources. However, the necessary model parameters, growth rates and attrition rates for each weight class, are not readily accessible. To estimate values for these variables, the market hog simulation model was used in conjunction with a non-linear optimization technique. The approach is an application of optimal control theory, and is simply a method of estimating the growth and attrition parameters which cause the model to most closely approximate observed slaughter and inventory data.

Optimization Technique

The optimization technique used to determine parameter values for the model is the Complex Algorithm developed by Box (1). The method is a sequential search technique with the capability to solve for an optimal set of controls in a model. The objective of the technique is to maximize a performance measure of the system. The performance measure is generally a functional relation of some or all the output variables of the model. For example, the objective function could be stated in general form as:

$$\text{Maximize: } F(y_1, y_2, \ldots y_n, r_1, r_2, \ldots, r_n)$$
$$\text{Subject to: } G_j \leq U_j \leq H_j,\ j = 1, 2, 3, \ldots, m$$

where $y_1, \ldots, y_n$ are output variables, $r_1, \ldots, r_n$ are parameters of the functional form and G_j and H_j define the allowable range for the control variables, U_j.

The search for the set of control variables which maximize the value of the objective function begins by the user providing starting values for each control variable. From the original set of values, K-1(=m) additional sets of values are generated from user supplied random numbers between 0 and 1. These random numbers are represented by the variable Z_j in the equation below.

$$U_j = G_j + Z_j (H_j - G_j), \qquad j = 1, 2, 3, \ldots, m$$

Each set of values generates a control path for the model which is used to evaluate the performance measure. Following the initial analysis of the K points, the algorithm rejects the control path yielding the minimum value for the objective function and seeks to replace it through an iterative search procedure to locate the optimum set of values for the control variables.

Each set of control variables tested may be represented by a vector, X_{ij}, where i refers to the control path and j represents the particular control variable. New values to be tested are computed by:

$$X_{ij}(\text{new}) = \bar{X}_{jc} + \alpha[X_{jc} - X_{ij}(\text{old})]; \qquad j = 1, 2, 3, \ldots, m$$

X_{jc} is the centroid for control variable j and is equal to the arithmatic average of the remaining K-1 values for control variable j. The X_{ij}(new) representing new values for the control variables for control path i is evaluated by generating a value for the performance measure with the model. This technique is designed to search for control paths leading to higher values for the performance measure. Convergence on the optimum set of values for the control variables is assumed to take place when the values for the performance measure are within β units of each other for γ consecutive iterations. The parameters, β and γ, are also supplied by the user.

In the market hog model the control variables are the growth rates and attritions by weight. The set of control variable values considered to be optimal are those values which cause the model to generate slaughter numbers of barrows and gilts and ending inventories for market hogs which are most closely in agreement with reported data.

Estimation of Model Parameters

The performance measure selected to evaluate generated control variables was based on intended use of the model and data consideration. For projection purposes, a desirable model characteristic is that slaughter projections be accurate. Also, in the judgment of those involved, slaughter data are likely more reliable than available inventory data. Therefore, heavier emphasis was given to slaughter numbers in the objective function.

The objective function used in generating historical values for growth rates and attrition rates is designed to minimize the errors for output variables in the system and is given by:

$$
\begin{aligned}
F(I) = {} & [(SL1 - SL1') \div SL1]^2 * 2 + [(SL2 - SL2') \div SL2]^2 * 2 \\
& + [SL3 - SL3') \div SL3]^2 * 2 + [(SLT - SLT') \div SLT]^2 * 3 \\
& + [(POF4 - POF4') \div POF4]^2 + [(POF3 - POF3') \div POF3]^2 \\
& + [(POF2 - POF2') \div POF2]^2 + [(POF1 - POF1') \div POF1]^2 \\
& + [(POFT - POFT') \div POFT]^2 * 3
\end{aligned}
$$

where SL1 = slaughter in month 1 of quarter,

SL2 = slaughter in month 2 of quarter,

SL3 = slaughter in month 3 of quarter,

SLT = quarterly total slaughter,

POF4 = ending inventory of market hogs less than 60 lbs.,

POF3 = ending inventory of market hogs 60-119 lbs.,

POF2 = ending inventory of market hogs 120-179 lbs.,

POF1 = ending inventory of market hogs greater than 180 lbs.,

POFT = total ending inventory of market hogs, and

the symbol "´" denotes estimated values generated by the model.

Because the Box Algorithm searches for a maximum and a minimization is desired, the objective function used as a performance measure is the additive inverse of the one presented.

As a method of simulating a continuous process, this technique is restricted by incomplete and periodic reporting of data. Because of this, several approximations of reality must be assumed for model operation. The average growth rate for hogs within each weight groups is assumed to be constant throughout individual quarters. Attrition from market hog inventories is assumed to occur at a constant rate within the quarter. The rate of pig production from farrowing operations is presumed to produce a flow of pigs into market hog inventories which remains fixed by months in the quarter. Also, the live slaughter weight is assumed fixed during the quarter and constant for each hog completing the growth process.

Historical values for the model parameters were generated independently for each quarter for the 1965-1976 period. These values are reported in Table II along with some measures of the model performance in tracking output variables using the optimal parameter estimates. The seasonal pattern for growth rates is very distinctive, usually peaking in the third quarter. The rate of attrition for each weight category appears to be somewhat high but does include farm slaughter of hogs, deaths, outshipments and any other possible sources of loss. The variation in calculated attrition rates offers evidence that these parameters were used by the model to absorb random shocks, possibly caused by errors in sampling data.

TABLE II

CALCULATED GROWTH AND ATTRITION RATES BY WEIGHT CLASSIFICATION
FOR MARKET HOG INVENTORIES, 1965-1976

Year/ Quarter	Growth Rates <60	Growth Rates 60-119	Growth Rates 120-180	Growth Rates >180	Attrition Rates <60	Attrition Rates 60-119	Attrition Rates 120-180	Attrition Rates >180	Quarterly Slaughter Percentage Error	Average Percentage Error For Inventories
1965 2	.648	1.039	1.258	1.749	.042	.023	.054	.006	.04	1.46
3	.735	1.204	1.424	1.620	.020	.082	.026	.096	.33	3.37
4	.614	.858	1.083	1.401	.049	.071	.022	.024	.27	.97
1966 1	.607	1.002	1.155	1.530	.076	.041	.054	.013	.04	1.83
2	.659	1.104	1.206	1.987	.055	.035	.012	.078	.17	.81
3	.754	1.216	1.370	1.689	.031	.023	.030	.047	.23	5.06
4	.627	.910	1.093	1.427	.032	.013	.062	.26	.01	1.54
1967 1	.660	1.056	1.286	1.671	.051	.026	.069	.011	.30	2.65
2	.665	1.095	1.195	1.885	.056	.025	.039	.024	.04	1.57
3	.741	1.246	1.416	1.815	.034	.024	.015	.058	.06	2.53
4	.642	.935	1.151	1.474	.030	.035	.045	.030	.01	1.27
1968 1	.688	1.038	1.319	1.580	.085	.015	.079	.013	.45	4.23
2	.678	1.169	1.279	1.757	.027	.066	.010	.077	.07	1.36
3	.746	1.210	1.486	1.629	.014	.046	.025	.029	.03	.37
4	.637	.951	1.164	1.465	.035	.007	.051	.007	.18	1.26
1969 1	.659	1.048	1.293	1.484	.035	.027	.060	.026	.10	2.78
2	.673	1.091	1.257	1.630	.052	.034	.055	.035	.00	.37
3	.711	1.162	1.459	1.642	.029	.067	.027	.029	.14	1.92
4	.636	.975	1.174	1.501	.025	.034	.087	.014	.78	1.76
1970 1	.653	1.018	1.242	1.704	.044	.071	.031	.032	.36	1.16
2	.688	1.112	1.279	1.898	.039	.020	.016	.044	.06	.67
3	.706	1.147	1.448	1.748	.021	.044	.035	.072	.04	1.22
4	.646	.997	1.216	1.501	.035	.016	.056	.026	.16	1.57

TABLE II (Continued)

Year/ Quarter	Growth Rates <60	Growth Rates 60-119	Growth Rates 120-180	Growth Rates >180	Attrition Rates <60	Attrition Rates 60-119	Attrition Rates 120-180	Attrition Rates >180	Quarterly Slaughter Percentage Error	Average Percentage Error For Inventories
1971 1	.712	1.095	1.231	1.558	.034	.041	.100	.030	.94	.99
2	.664	1.005	1.177	1.651	.063	.043	.018	.049	.16	1.86
3	.698	1.191	1.452	1.784	.014	.034	.052	.034	.07	.39
4	.654	1.056	1.222	1.529	.008	.046	.031	.065	.09	1.79
1972 1	.616	1.039	1.186	1.605	.049	.025	.043	.035	.12	.81
2	.689	1.096	1.207	1.862	.057	.022	.011	.052	.04	2.83
3	.651	1.175	1.394	1.857	.007	.047	.011	.099	.36	1.99
4	.636	1.011	1.273	1.625	.030	.032	.029	.029	.13	.84
1973 1	.627	1.001	1.213	1.501	.045	.062	.100	.030	.22	.70
2	.639	1.043	1.183	1.674	.051	.027	.044	.028	.00	1.47
3	.609	1.092	1.258	1.851	.014	.048	.028	.074	.65	4.52
4	.616	.966	1.247	1.518	.015	.011	.089	.009	.36	1.28
1974 1	.598	.965	1.189	1.580	.076	.025	.100	.026	.89	.96
2	.651	1.011	1.279	1.777	.043	.043	.061	.018	.25	1.20
3	.623	.984	1.209	1.663	.041	.020	.098	.011	2.13	2.90
4	.602	.932	1.212	1.568	.055	.068	.055	.014	.38	1.02
1975 1	.598	.979	1.224	1.564	.055	.044	.080	.012	.18	.53
2	.636	.948	1.238	1.608	.047	.056	.038	.021	.24	1.89
3	.640	1.099	1.355	1.665	.011	.011	.083	.086	.05	1.05
4	.610	.993	1.222	1.682	.038	.008	.070	.021	.18	1.97
1976 1	.620	1.010	1.264	1.770	.022	.062	.071	.019	.32	.86
2	.669	1.078	1.294	1.833	.047	.034	.030	.034	.37	1.81
3	.663	1.148	1.404	1.665	.028	.033	.014	.030	.08	1.61
4	.642	1.093	1.400	1.720	.028	.049	.007	.030	.03	.36

Econometric Equations of the Hog Model

The remaining components of the hog model are estimated econometric relationships and are designed to provide input into the market hog component and to transform its output into projections of aggregate pork production.

Breeding Hog Inventory

The breeding hog inventory contains all the hogs not classified as market hogs. Factors hypothesized to influence production decisions and the size of the breeding hog inventory are the price of output (barrows and gilts) and the cost of production. The primary variable cost factor for hog operations is the price of corn.

$$BHI = \underset{}{2440.314} + \underset{(3.70)}{153.650}\,(PBG \div CRNP)_{t-2} + \underset{(2.23)}{94.312}\,(PBG \div CRNP)_{t-6}$$

$$+ \underset{(.58)}{57.752}\,D2 - \underset{(4.66)}{523.693}\,D3 - \underset{(1.76)}{189.840}\,D4 - \underset{(2.12)}{32.092}\,TQ$$

$$R^2 = .848 \qquad \underset{(7.15)}{\rho = .736} \qquad DW = 1.82$$

The estimated relationship includes the ratio of the price of barrows and gilts to the price of corn lagged two and six quarters. The two period lag represents the impact on short run planning while the six period lag is hypothesized to reflect the effect of the profit measure on longer run decision making. Both of the coefficients for these variables carry the expected sign, but the variable lagged two periods displays more signficance. Dummy variables are also included to account for seasonal variation within the year. The negative coefficient on the trend term is presumed to explain the decline in the number of breeding animals required to produce a given output of pork due to increased proficiency in hog production.

Quarterly Pig Crop

The pig crop equation is based on primarily the same set of variables used to explain variation in breeding hog inventories. The hog-corn price ratio is used in two lagged forms which suggest both a short and long run impact on decision making. Also contained in the pig crop equation is the dependent variable lagged four periods which provides information on the level of production one year past. This variable accounts for much of the seasonality in production and allows changes in production to be made through an adjustment process. The dummy variables on the hog-corn ratio permits pig crop output to vary seasonally with profit potential.

$$
\begin{aligned}
PIGC = {} & -797.921 + \underset{(3.86)}{591.921}\,(PBG \div CRNP)_{t-2} + \underset{(3.56)}{280.191}\,(D2) \\
& (PBG \div CRNP)_{t-2} + \underset{(2.50)}{98.346}\,(D3)(PBG \div CRNP)_{t-2} + \underset{(3.41)}{111.438}\,(D4) \\
& (PBG \div CRNP)_{t-2} + \underset{(1.15)}{147.587}\,(PBG \div CRNP)_{t-7} + \underset{(11.13)}{.7333}\,PIGC_{t-4}
\end{aligned}
$$

$$
R^2 = .943 \qquad \rho = \underset{(7.31)}{.690} \qquad DW = 1.90
$$

Calculation of Breeding Herd Replacements

For data collection purposes, pigs are classified as market hogs or breeding hogs when born. Therefore, to use the estimated pig crops as inflow into the continuous delay model for market hogs, some estimate of the proportion of the pig crop retained for breeding purposes must be obtained. One means of computing this number is through an identity relationship which states the end of quarter breeding hog inventory to be equivalent to the breeding hog inventory of the previous quarter, plus pigs retained for breeding purposes less leakages from the breeding hog stock.

$$BHI_t = BHI_{t-1} + REPL_t - SABS_t - SABD_t$$

The approach utilized in gaining an estimate of the number of pigs entering the stock of breeding animals was one of estimating the leakages, $SABS_t$ and $SABD_t$, and computing $REPL_t$ as a residual quantity.

Quarterly Sow and Boar Slaughter

The equation for the commercial slaughter of sows and boars is specified to be functionally related to a measure of profit in hog production, the hog corn ratio, and a quantity variable to represent the level of current production. A lagged form of the breeding hog inventory was tested as an explanatory variable but did not perform as well as the pig crop for the previous quarter. One explanation of this may be in the fact that gilts are often bred only once before slaughter. This would cause the pig crop to be a reliable estimate of sows available for slaughter. Also, the practice of classifying hogs as breeding hog inventory when first born tends to make the size of the inventory a deceptive indicator of breeding hogs available for slaughter during expansion phases of the hog cycle.

$$SABS = 227.346 + \underset{(4.78)}{.0635}\, PIGC_{t-1} - \underset{(2.33)}{37.695}\, (PBG \div CRNP)_{t-1} - \underset{(1.88)}{30.816}$$

$$(PBG \div CRNP)_{t-5} + \underset{(8.91)}{464.007}\, D2 - \underset{(.10)}{12.860}\, D3 + \underset{(8.56)}{356.842}\, D4$$

$$R^2 = .804 \qquad \rho = \underset{(5.44)}{.608} \qquad DW = 2.09$$

The equation was estimated with autoregressive least squares. The fit of the equation is not exceptionally good, but the statistical significance of most of the coefficients tends to support the estimated form.

No data are available on the death rate for breeding hogs. The only figure reported in published data sources is the annual deaths for all hogs. To approximate breeding hog deaths an assumption of a constant death rate for all quarters within the year was assumed. The annual death rate from breeding hog numbers was also assumed to be equal to the rate for all hogs. Therefore, deaths during each quarter are assumed to be a constant proportion of the breeding hog inventory each quarter. For projection purposes, the annual death rate for future years was assumed to be a constant equal to the death rate over the 1965-1976 interval.

Monthly Pig Crops

Pig crops were reported on a monthly basis from 1958 to 1967. From 1968 to the present only quarterly data are available. Because the pig crop less breeding herd replacements is used as the source of inflow into the continuous delay model of the market hog sector, a measure of inflow more precise than simply a quarterly average was deemed necessary. The limited data problem forced the development of some means to transform the projected quarterly pig crop into a monthly form. In observing the available historical monthly data, strong trends were noted in the proportion of quarterly slaughter occurring by months. The trends, in general, reflected a movement away from traditional seasonal farrowing patterms. In view of this fact, the decision was made to estimate the trends with regressions rather than a more simple estimator such as the average proportions for the historical period.

$$L(DEC) = -1.8792 + \underset{(11.35)}{.1996}\, L(TIME)$$

$R^2 = .942 \qquad DW = 1.82$

$$L(FEB) = -.5875 - \underset{(9.69)}{.1089}\, L(TIME)$$

$R^2 = .922 \qquad DW = 1.28$

$$L(MAR) = -.8748 - \underset{(5.00)}{.0055}\, L(TIME)$$

$R^2 = .758 \qquad DW = 2.86$

$$L(MAY) = -1.5557 + \underset{(5.15)}{.0759}\, L(TIME)$$

$R^2 = .768 \qquad DW = 1.92$

$$L(JUN) = -1.3367 + \underset{(8.97)}{.1009}\, L(TIME)$$

$R^2 = .909 \qquad DW = 1.82$

$$L(AUG) = -.7825 - \underset{(6.57)}{.0944}\, L(TIME)$$

$R^2 = .843 \qquad DW = 1.42$

$$L(SEP) = -.5799 - \underset{(4.06)}{.0424}\, L(TIME)$$

$R^2 = .777 \qquad DW = 2.26$

$$L(NOV) = -1.9251 + \underset{(4.06)}{.0835}\, L(TIME)$$

$R^2 = .673 \qquad DW = 1.32$

After testing several functional types, the final form of the equations estimating monthly proportions of quarterly pig crops was chosen to be the double-log. Such a form provides for a non-linear relationship between the observed proportions and the trend variable. To force the monthly proportions to sum to unity, equating total monthly pig crops to quarterly, one month for each quarter was not estimated by regression and computed as a residual of the other two. The eight equations for monthly proportions were estimated with ordinary least squares. The natural log for each variable is denoted by "L( )".

Slaughter Weight of Barrows and Gilts

To utilize the market hog model to project barrow and gilt slaughter and ending inventories for market hogs, a projected ending slaughter weight must be provided along with the parameters describing the growth process and system leakage. The live weight of barrows and gilts slaughtered is hypothesized to be related to both seasonal and economic factors. The economic explanatory variable in the estimated equation represents the relation between a recent change in the output price and the price of the primary input. The expected behavior of producers is to hold hogs for longer periods as prices are increasing, resulting in heavier weights. The estimated coefficient supports this hypothesis. The justification for a linear trend term is that improved breeding and feeding practices have allowed the production of a lean hog capable of attaining a heavier finishing weight.

$$\begin{aligned} BGLVWT = {} & 114.580 + \underset{(2.03)}{.4202}\ [(PBG_{t-2} - PBG_{t-4}) \div CRNP_{t-2}] \\ & + \underset{(1.01)}{.621}\ D2 - \underset{(6.20)}{4.501}\ D3 - \underset{(6.61)}{3.999}\ D4 + \underset{(5.72)}{.143}\ TQ \end{aligned}$$

$$R^2 = .8002 \qquad \rho = \underset{(4.72)}{.492} \qquad DW = 1.678$$

The equation is estimated over the 1958-1976 period, with autoregressive least squares, and although the R^2 is not high, the average absolute percentage error (not reported) for the equation is less than one.

Growth Rates of Market Hogs

The equations used to estimate historical growth rates are estimated with ordinary least squares over the 1965 to 1976 period and use as dependent variables the output of the market hog model reported in Table II. Growth rates are presumed to be affected by seasonal influences and the economic conditions of hog production. If the price of market hogs is high, producers are induced to finish hogs as rapidly as possible. Conversely, if corn price is high, feeding practices may be adjusted to an extent which affects the realized growth rates of the industry. To reflect these influences in estimated equations, different lags for the price of corn and the price of barrows and gilts were tested. The lag of two quarters finally used appears to portray a situation in which hog feeders carry stocks of feed and only become affected by market prices as new feed purchases become necessary. The lag of two periods on barrow and gilt price may simply represent a behavioral lag in decision making.

$$GR4 = .6797 - \underset{(3.83)}{.0139}\ CRNP_{t-2} + \underset{(1.75)}{.0215}\ D2 + \underset{(4.01)}{.0492}\ D3 - \underset{(.86)}{.0105}\ D4$$

$R^2 = .511 \qquad DW = 1.86$

$$GR3 = 1.065 - \underset{(2.56)}{.0310}\ CRNP_{t-2} + \underset{(1.13)}{.0016}\ PBG_{t-2} + \underset{(1.92)}{.045}\ D2 + \underset{(5.47)}{.130}\ D3 - \underset{(2.08)}{.048}\ D4$$

$R^2 = .652 \qquad DW = 1.53$

$$GR2 = 1.217 - \underset{(.80)}{.0122}\ CRNP_{t-2} + \underset{(1.07)}{.0019}\ PBG_{t-2} + \underset{(.03)}{.001}\ D2 + \underset{(5.05)}{.151}\ D3 - \underset{(2.08)}{.029}\ D4$$

$R^2 = .546 \qquad DW = 1.82$

$$GR1 = 1.525 - \underset{(2.25)}{.0447}\ CRNP_{t-2} + \underset{(2.88)}{.0066}\ PBG_{t-2} + \underset{(3.64)}{.196}\ D2 + .142\ D3 - \underset{(2.08)}{.029}\ D4$$

$R^2 = .615 \qquad DW = 1.59$

Attrition Rates of Market Hogs

The attrition rates by weight categories which were generated by applying the optimization procedure to the market hog model were not found to have any distinctive seasonal pattern. In addition, no significant trend was observable and attempts to relate the attrition rates to economic variables were unsuccessful. Thus, projected values for total attrition attributable to each weight class are assumed constant. Estimates of the constants were obtained by simply averaging the total and proportions of attrition. These estimates are listed below.

Attrition rate for hogs less than 60 = .0383

Attrition rate for hogs 60-119 = .0374

Attrition rate for hogs 120-180 = .0481

Attrition rate for hogs greater than 180 = .0357

Total rate of attrition = .0397

Average Dressed Weight of Slaughter Hogs

One output of the market hog model is quarterly slaughter of barrows and gilts. An equation to project the quarterly slaughter of sows and boars was presented earlier in this section. To obtain an estimate of domestic commercial pork production, the average dressed weight of all hogs slaughtered must be determined.

$$\begin{aligned} HOGWGT = 6.246 &+ \underset{(2.30)}{.00395}\ SABS_t - \underset{(4.14)}{.00081}\ BGS_t + \underset{(4.60)}{.5267}\ BGLVWT \\ &- \underset{(1.18)}{1.338}\ D2 - \underset{(.71)}{1.217}\ D3 + \underset{(2.16)}{2.589}\ D4 + \underset{(14.74)}{.4427}\ TQ \end{aligned}$$

$R^2 = .946 \qquad DW = 1.85$

Included in the equation to project dressed slaughter weights are the levels of sow and boar slaughter and barrow and gilt slaughter. The slaughter weight for barrows and gilts is generally less than that for breeding hogs which is reflected in the estimated inverse relation between the slaughter of barrows and gilts and average dressed weight for all hogs. The positive sign on the coefficient for the trend variable indicates average weights are increasing over the time period of estimation. The equation is estimated by ordinary least squares over the 1958-1976 period.

Pork Production and Available Domestic Supplies

Commercial pork production is then derived as a multiplicative identity of hog slaughter and average dressed weight. A conversion factor of .001 is used to obtain an estimate of pork production expressed in million pounds.

$$PORK = HOGWGT_t * (SABS_t + BGS_t) * (.001)$$

Available domestic supplies on a quarterly basis consist almost entirely of quarterly domestic production. There is, however, a small quantity of pork imported and exported from the U. S., with total imports exceeding exports by a level of generally under three percent of total production. Imports and exports enter the model as exogenous variables, and together with domestic production identify quarterly domestic pork supplies.

$$PORKS = PORK + PIMP - PEXP$$

Beef Model

The beef production system is similar to that for hogs, but differs in several crucial aspects. Although both of the major meat production systems in the U. S. are strongly dependent on the feed grain subsector for inputs, pork production is more vulnerable to fluctuations in grain prices. This fact is due to the biological differences in the two animals. Pasture and forage can provide nutrients to cattle for growth and can be substituted for grain. Hogs are unable to utilize forage and must be fed grain to survive and grow to maturity.

Another important difference in the production of beef and pork is the time required to complete the growth process. From the time a pig is born until slaughter weight is realized usually takes six to nine months. For a calf which is grazed for a period following weaning and then placed on a grain ration until slaughter, the process lasts from 18 to 24 months. Thus, the biological lags in production are considerably longer for beef than for pork.

Econometric Equations for the Beef Model

Cow inventories in the U. S. provide the foundation for the production of cattle. For this study the cow inventory is separated into two classifications, beef and dairy. Although both contribute to the production of beef, the economic motives determining numbers in the two classes are presumed to be different.

Beef Cow Inventory

The primary product of beef cow-calf operations are weaned calves and feeder animals. There are many inputs in a calving enterprise but consist principally of grazing, supplement feeds, machinery and labor, and investment costs. To relate the profit potential of beef production at the cow-calf level a variable was developed to compare the value of output to production costs. Using budgets constructed for Oklahoma farms and ranches (2) and published indices for various agricultural inputs, a hypothetical annual cost of production series was constructed for the 1947 to 1976 interval.[1] The series is expressed in cost per hundred-weight to make the series comparable to the calf price per hundred-weight reported for various livestock markets.

The reported equation explaining variation in beef cow numbers is estimated with the dependent variable in the form of percentage change. This approach is preferred to the approach of simply using the current value of inventory variable, because the number of beef cows have more than doubled over the estimation period. The change in the absolute number of beef cows due to a change in profit potential would be expected to be larger for a larger production base. The only explanatory variable is the ratio of feeder calf price to the cost of production variable. The use of this variable lagged one and two years depicts a decision making process for the cow-calf operator that is more long run in nature than that for pork. Fixed costs make up a large proportion of total costs in raising calves which permits producers to continue production even as output prices begin falling.

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[1] From a 1975 Oklahoma cow-calf enterprise budget, costs were separated into four aggregated components: investment, labor, feed and other which includes veterinary costs, hauling, expense and general maintenance. The index as defined is given by: [\$120.00 * (Machinery Cost Index $\div$ Machinery Cost Index$_{1975}$) + 14.0 * Utility Cow Price) * Interest Rate + Wage Rate * 8.0 + 66.63 * (Hay Price$_t$ $\div$ Hay Price$_{1975}$) + 18.00 * (PPD$_t$ $\div$ PPD$_{1975}$)] $\div$ 4.0. The \$120.00 is a measure of machinery investment costs per cow in 1975. Previous years were approximated using the index of machinery prices paid by farmers. The 14.0 factor for cows includes consideration of bulls, breeding herd replacements and the fact that the utility cow price is generally a low estimate of the prices paid for breeding cows. The interest rate used is the cost of borrowing from Production Credit Associations. Eight hours of labor were required by the budget and the farm wage rate was used to measure the hourly rate. Price of hay received by farmers was used as the forage cost with changes in the cost of "other" items assumed to be represented by prices paid index for all production items. The cost per cow is then divided by 4.0 to obtain an estimate of cost per hundred weight for calves produced. This assumes 89 percent survival rate of 450 pound market calves.

$$\frac{BCI_t - BCI_{t-1}}{BCI_{t-1}} = -.1076 + \underset{(1.22)}{.0341}\ PROF_{t-1} + \underset{(4.53)}{.1361}\ PROF_{t-2}$$

$$R^2 = .718 \qquad \rho = \underset{(2.75)}{.480} \qquad DW = 1.29$$

The equation is estimated from annual data over the years 1951 to 1976. The estimation technique is autoregressive least squares. The coefficients have theoretically consistent signs, and the R^2 for the equation is farily high in consideration of the form of the dependent variable.

Dairy Cow Inventory

Dairy cow inventories have been gradually declining since 1950 and the current size of the herd is much smaller than at the beginning of the estimation period. For this reason the dependent variable was put in the percentage change form for estimation. The explanatory variables contined in the equation are the blend milk price deflated by the index of prices paid by farmers and the average production of milk per cow. The price of milk is considered the primary economic motivation of dairy operators. Milk production per cow which has increased substantially since 1950 provides a measure of the technical production capabilities of a given herd size.

$$\frac{DCI_t - DCI_{t-1}}{DCI_{t-1}} = -.0493 + \underset{(1.48)}{.02462}\ \frac{BMP_{t-2}}{PPD_{t-2}} - \underset{(.67)}{.0000033}\ MPC_{t-2}$$

$$R^2 = .484 \qquad \rho = \underset{(3.14)}{.592} \qquad DW = 1.42$$

The equation for dairy cows was also estimated from annual data over the 1951-1976 period. The estimation technique is autoregressive least squares. Although the coefficient signs provide evidence of expected relationships the statistical significance for both coefficients is low. The overall fit of the equation is respectable for a dependent variable in the form of percentage change.

Net Calf Crop

The annual calf crop is derived directly from the two cow inventories. An annual figure for calf deaths is also reported in published data sources. A new calf crop figure for the number of surviving calves may then be derived by the difference in total calvings and calf deaths.

$$NCCROP = \underset{}{1890.87} + \underset{(5.78)}{.6972}\, BCI_t + \underset{(3.10)}{.6877}\, DCI_t + \underset{(1.54)}{1499.365}\, PROF_{t-1}$$

$$R^2 = .964 \qquad \rho = \underset{(3.98)}{.677} \qquad DW = 1.66$$

The equation for net calf crops specifies the annual number of calves produced to be a function of both beef and dairy cow inventories. The separation was maintained in this equation, recognizing the possibility that the production and survival rates for beef and dairy calves may not be identical. The third explanatory variable in the equation represents the value of the calf relative to its production cost. As cattle prices rise, both beef cow and dairy operators are likely to make a more conscious effort to save the calves which are born.

This equation was estimated with autoregressive least squares over the time period 1951-1976. All the coefficients have positive signs in agreement with hypothesized relations. In addition, the coefficients for the beef and dairy cow inventory variables are near the same value which might be expected.

Placements on Feed

Following birth and warning, calves may either be grazed for a period or placed into feedlots on a ration of grain. The quarterly placements of cattle on feed is hypothesized to be a function of available calves and the profitability of feeding grain to cattle. In the estimated equation, the net calf crop of the previous year is used as a proxy for calves available to be placed. A ratio of the price of slaughter steers and corn price is an indicator of the output value relative to the cost of an important input. The price of feeder steers is also contained in the equation to reflect the purchase cost of animals placed. The proportion of cattle being fed has displayed a general increase over the sample period. To depict a recent level of cattle feeding, placements lagged four periods are contained in the equation. The dummy variable assumes a value of one between the third quarter of 1973 and the first quarter of 1975. Indications in the data are that the government price freeze on beef in 1973 had a depressing impact on the expectations of cattle feeders during this period.

$$\begin{aligned} TOTPL = -6177.85 &+ \underset{(3.28)}{.1895}\ NCCROP_{t-4} + \underset{(2.56)}{77.042}\ (SSP_{t-1} \div CRNP_{t-1}) \\ &- \underset{(.54)}{11.278}\ FSP_{t-1} + \underset{(4.06)}{.5164}\ TOTPL_{t-4} - \underset{(.47)}{82.34}\ D2 + \underset{(1.42)}{237.11}\ D3 \\ &+ \underset{(3.95)}{1476.67}\ D4 - \underset{(2.72)}{791.89}\ DUM73 \end{aligned}$$

$R^2 = .936 \qquad DW = 1.91$

The equation was estimated with ordinary least squares over the 1963–1976 interval. The dependent variable is 23-state placements which is the principal published data series. All the variable coefficients carry expected signs although some are not significant at the five percent level of rejection.

Fed Marketings and Slaughter

Cattle which are placed on feed are eventually marketed as fed animals for the purpose of slaughter. Because cattle are placed on feed at weights ranging from 350 to 900 pounds, the feeding time necessary to produce a mature animal varies substantially. To project 23-state fed marketings from cattle placed on feed, four equations were estimated. The justification for four separate relations lies in the fact that placement weights are highly seasonal (24). Average placement weights are generally much lower in the fourth and first quarters when spring calves become available for feeding.

$$\text{FMKTG23(1st quarter)} = 1622.60 + \underset{(.52)}{.0487}\ \text{TOTPL}_{t-1} + \underset{(3.79)}{.5000}\ \text{TOTPL}_{t-2} + \underset{(3.57)}{.2295}\ \text{TOTPL}_{t-3}$$

$R^2 = .976 \qquad DW = 1.35$

$$\text{FMKTG23(2nd quarter)} = 154.21 + \underset{(2.20)}{.5685}\ \text{TOTPL}_{t-1} + \underset{(1.63)}{.3288}\ \text{TOTPL}_{t-2} + .0240\ \text{TOTPL}_{t-3}$$

$R^2 = .869 \qquad DW = 2.52$

$$\text{FMKTG23(3rd quarter)} = 192.06 + \underset{(1.53)}{.2457}\ \text{TOTPL}_{t-1} + \underset{(.05)}{.0153}\ \text{TOTPL}_{t-2}$$

$$+ \underset{(2.62)}{.5499}\ \text{TOTPL}_{t-3}$$

$R^2 = .797 \qquad DW = 1.69$

$$\text{FMKTG23(4th quarter)} = 375.95 + \underset{(.87)}{.2427}\ \text{TOTPL}_{t-1} + \underset{(.47)}{.1285}\ \text{TOTPL}_{t-2}$$

$$+ \underset{(2.40}{.6392}\ \text{TOTPL}_{t-3}$$

$R^2 = .810 \qquad DW = 1.24$

$$\text{FEDMKTG} = 64.163 + \underset{(1.49)}{.2500}\ (\text{COF39} - \text{COF23}) + \underset{(164.45)}{1.0209}\ \text{FMKTG23} -$$

$$\underset{(3.17)}{42.158}\ \text{D2} - \underset{(7.75)}{110.472}\ \text{D3} - \underset{(7.32)}{104.289}\ \text{D4}$$

$R^2 = .999 \qquad DW = 1.17$

The estimation technique for the four equations is ordinary least squares. The observation period included in the sample is 1963 to 1976. Although variables other than lagged placements were tested, none were helpful in explaining the variation in marketings.

The only national data series currently reported for cattle on feed is the 23-state survey. Although the 23-states included in this sample make up over 90 percent of all cattle fed in the U. S., an estimate of fed slaughter more closely approximating the total is desirable. Data for fed marketings from 39-states is available for years up to 1970 (3). For practical purposes this series may be considered as fed cattle slaughter for the U. S. Because January 1 inventories of cattle on feed are reported for all states, an equation was formulated to expand the estimate for fed marketings in 23 states to a 39-state estimate. This quarterly equation is estimated for the years 1960 to 1970 with ordinary least squares. Although the Durbin-Watson statistic offers some indication of autocorrelated errors, the first order coefficient was found to be insignificant when estimated with autoregressive least squares.

Fed Beef Production

To obtain an estimate of fed beef production from 39-state fed marketings, a relationship for average dressed slaughter weights for fed cattle must be provided. The weights of fed cattle tend to vary within the year with the seasonal low typically occurring in the third quarter. Several economic variables which might affect slaughter weights were tested with limited success. The final estimation form of the equation contains the moving average of slaughter steer price lagged three, four and five quarters. This length of lag may be justified on the basis that feeders tend to place cattle on feed at heavier weights as the output price increases and heavier placement weights generally provide for heavier finishing weights. The trend term included in the equation may reflect the response of cattle feeders to the consumer's desire for a leaner product.

$$\begin{aligned} FEDW = {} & 281.243 + \underset{(5.35)}{1.904}\,[(SSP_{t-3} + SSP_{t-4} + SSP_{t-5}) \div 3.0] \\ & - \underset{(2.93)}{4.633}\,D2 - \underset{(15.03)}{26.716}\,D3 - \underset{(6.20)}{9.702}\,D4 - \underset{(4.35)}{.535}\,TQ \end{aligned}$$

$$R^2 = .832 \qquad \rho = \underset{(5.50)}{.568} \qquad DW = 1.93$$

The sample period of estimation for the quarterly relationships includes the years 1958 to 1976. Autoregressive least squares is the estimation technique and the reported t-values lend support to the specification.

Fed beef production may be obtained as a multiplicative identity of fed slaughter and dressed weights. For unit conversion, the factor of .001 is used to transform the beef production figure from thousand pound units to million pounds.

FBEEF = .001 (FEDMKTG * FEDW)

Nonfed Slaughter

Another source of domestic beef is the slaughter of animals which are finished on grass and forage. This non-fed beef is comprised of animals culled from breeding herds as well as steers and heifers which are never placed on a grain ration before slaughter. Three equations for the separate categories were specified to arrive at an estimate of total non-fed cattle slaughter.

Cow Slaughter. The economic conditions affecting the inventories of beef and dairy cows also heavily influence the level of commerical cow slaughter. The January inventory of cows is included in the cow slaughter equation to represent the normal culling rate due to aging of the cow herd. The ratio of the blend price of milk to the index of prices paid by farmers is used to represent the profitability of dairy operations. The eight quarter lag is equivalent to the two year lag specified in the dairy cow inventory equation.

$$\text{COWS} = \underset{}{-465.56} + \underset{(9.76)}{.1203}\,(\text{BCI}_t + \text{DCI}_t) - \underset{(.27)}{33.307}\,(\text{BMP} \div \text{PPD}_{t-8})$$

$$- \underset{(6.42)}{616.920}\,\text{BPROF6}_t - \underset{(3.74)}{228.686}\,(\text{D3} * \text{BPROF6}_t) - \underset{(4.73)}{283.838}$$

$$(\text{D4} * \text{BPROF6}) - \underset{(7.64)}{1204.84}\,\text{D1} - \underset{(8.05)}{1279.69}\,\text{D2} - \underset{(2.25)}{366.11}\,\text{D3}$$

$$R^2 = .903 \qquad \rho = \underset{(6.86)}{.595} \qquad \text{DW} = 1.82$$

The variable BPROF6 is a lagged six quarter moving average of the ratio of feeder calf price to the cost of raising calves, weighted by a beef cow index. The justification for weighting the variable according to the size of the beef cow inventory is the same as that behind the use of a percentage change form of the dependent variable in the beef cow inventory equation. As the size of the beef cow herd increases, the absolute change in cow slaughter from a given change in profit outlook cannot be expected to remain constant. The dummy variables on the beef profit variable indicate the slaughter response to profit potential also varies across seasons.

The quarterly cow slaughter equation was estimated with autoregressive least squares over a sample period 1952-1976. All the coefficients have theoretically consistent signs and are statistically significant with the exception of the dairy profit variable.

Bull and Stag Slaughter. Another category of non-fed slaughter, bulls and stags, is strongly correlated with the slaughter of cows, which is reasonable since both are part of the breeding inventory. The hypothesis used in the equation specification is that the slaughter of bulls and stags generally lags cow slaughter. During periods of low beef prices, the culling rates may gradually increase. This causes a need for bulls to be retained for a period following the initial rise in cow slaughter. Bull and stag slaugther is also specified to be related to the relative number of beef and dairy cows. The positive coefficient obtained for the beef cow-dairy cow ratio implies the number of bulls associated with a beef herd of given size to be larger.

$$\begin{aligned} BSS = {} & 1.916 + \underset{(14.71)}{179.787}\,(BCI_t \div DCI_t) + \underset{(2.20)}{.0156}\,COWSHA_t \\ & + \underset{(8.55)}{.0179}\,(D2 * COWSMA_t) + \underset{(13.26)}{.0313}\,(D3 * COWSMA_t) \\ & + \underset{(10.25)}{.0222}\,(D4 * COWSMA_t) - \underset{(13.11)}{5.389}\,TQ \end{aligned}$$

$$R^2 = .922 \qquad \rho = \underset{(4.25)}{.401} \qquad DW = 1.88$$

The equation was estimated for the period 1951 to 1976 with autoregressive least squares.

<u>Nonfed Steer and Heifer Slaughter</u>. Nonfed steers and heifers may be viewed as the residual of cattle not placed on feed at some point in past periods. This is the basis for specifying the price of slaughter steers and the price of corn lagged three quarters to be related to the number of cattle going to slaughter from pasture. The index of pasture conditions is also in the equation, demonstrating that slaughter may increase when the situation for range plant growth worsens. The negative sign on the beef profit indicator shows slaughter of stock off farms will decline if economic conditions dictate a need for growth in the breeding herd.

$$NFSHS = 3113.97 - \underset{(1.52)}{15.579}\ PCON - \underset{(3.19)}{903.031}\ PROF_{t-1} - \underset{(.76)}{6.965}\ SSP_{t-3}$$

$$+ \underset{(4.56)}{317.78}\ CRNP_{t-3} + \underset{(1.06)}{57.12}\ D2 + \underset{(5.45)}{344.10}\ D3 + \underset{(5.16)}{293.66}\ D4$$

$$- \underset{(4.93)}{23.50}\ TQ$$

$$R^2 = .923 \qquad \rho = \underset{(2.01)}{.310} \qquad DW = 1.90$$

The equation for non-fed steers and heifers is estimated from quarterly data for the 1963-1976 period with autoregressive least squares. Although several coefficients are not statistically significant, all exhibit expected signs and the R^2 is at a respectable level.

Nonfed Beef Production and Available Domestic Supplies

The equation to estimate the average dressed weight of non-fed slaughter lumps all three categories of non-fed cattle together. The equation contains a trend term with a positive coefficient indicating a general increase in the average weight over the estimation period. The ratio of dairy cows to beef cows demonstrates the slaughter weight of dairy cows to be higher than beef. The two major components of non-fed slaughter, cows and steers and heifers, offer evidence that the average dressed cow weight is below that of steers and heifers. The estimation technique is autoregressive least squares and the period of estimation extends from 1963 to 1976.

$$NFEDW = 153.67 + \underset{(4.62)}{2.629}\ TQ + \underset{(2.51)}{384.486}\ (DCI_t \div BCI_t) - \underset{(4.71)}{.0315}\ COWS_t$$

$$+ \underset{(1.08)}{.0071}\ NFSHS - \underset{(1.00)}{3.77}\ D2 + \underset{(7.27)}{30.94}\ D3 + \underset{(5.73)}{22.92}\ D4$$

$$R^2 = .839 \qquad \rho = \underset{(2.20)}{.262} \qquad DW = 2.00$$

Like the equation for fed beef production nonfed beef production expressed in million pound units is a multiplicative identity of dressed weights and the slaughter across the three categories.

NFBEEF = .001 (NFEDW) *)COWS + NFSHS + BSS)

Imports of beef are generally low in quality and act principally as a substitute for domestically produced nonfed beef. Also, a small amount of beef is exported and shipped out of the U. S. Because beef imports are subject to quotas, they are considered exogenously determined on a quarterly basis. The identity relationship for quarterly domestic nonfed beef supplies is given below.

NFBFS = NFBEEF + BIMP - BEXP

Broiler Chicken Model

Broiler output for the U. S. has more than doubled since 1960. Per capita consumption has also grown substantially, increasing from 23.4 pounds in 1960 to 40.4 pounds per person in 1976. In comparison, pork consumption per capita has remained steady in the 60 to 70 pound range, with variability due primarily to the pork cycle (27). Thus, broiler chickens have become a third major meat category for the U. S. and appear to be very competitive with beef and pork for the consumer's food dollar.

Econometric Equations of Broiler Production

As a livestock group, the biological lag time in broiler production is much shorter than for cattle and hogs. The time interval between hatching and slaughter is normally under ten weeks. A production period of this length permits a quick supply response to market price signals, and the cycles often observed for beef and pork are not as readily noticeable in broiler production. This short production lag also allows for a very simplified modeling approach for broilers in a quarterly model.

Broiler Slaughter

The output of broilers for the U. S. is represented in this study as a single equation. The dependent variable, in the form of dressed weight production, is specified to be a function of the output price relative to the price of corn, a primary feed input. Quarterly intercept dummies are also included in the equation and their exhibited t-values indicate strong seasonality in production. The linear trend variable is intended to represent the increase in productivity caused by improved breeding and feeding practices over the time period of estimation.

$$\begin{aligned} \text{BROILER} = {} & 20.264 + \underset{(3.02)}{29.085}\,(\text{BFP}_{t-2} \div \text{CRNP}_{t-2}) + \underset{(14.84)}{204.544}\,\text{D2} \\ & + \underset{(12.51)}{198.395}\,\text{D3} + \underset{(2.32)}{32.244}\,\text{D4} + \underset{(17.19)}{17.825}\,\text{TQ} \end{aligned}$$

$$R^2 = .977 \qquad \rho = \underset{(6.10)}{.626} \qquad \text{DW} = 2.00$$

The equation was estimated from quarterly data for the 1960-1976 period with autoregressive least squares. The coefficients are all significant at the five percent level, and the R^2 indicates a good overall fit of the data.

Broiler Exports and Domestic Supplies

While broiler production in the U. S. has become more efficient and total output has expanded, the amount of production in excess of domestic consumption needs has also increased. To obtain an estimate of broiler production available for domestic consumption, an indicator of broiler exports and shipments outside the U. S. must be provided. The relationship estimated specifies broiler exports and shipments to a function of seasonal influences and the level of total broiler output for the quarter. The t-values and R^2 are not as high as might be desirable, but alternative specifications which included price variables and trend failed to improve the equation appreciably. Autoregressive least squares was used to estimate equation parameters for the 1960-1976 period.

$$BREXP = -7.41 + \underset{(1.41)}{.0416}\, BROILER - \underset{(.17)}{.911}\, D2 - \underset{(.24)}{1.684}\, D3 + \underset{(2.51)}{6.687}\, D4$$

$$R^2 = .705 \qquad \rho = \underset{(7.16)}{.809} \qquad DW = 2.24$$

Quarterly broiler supplies available for consumption in the domestic market is hypothesized to be the difference in production and exports. Little if any broiler meat is imported for consumption in the U. S.

$$BROILERS = BROILER - BREXP$$

Meat and Livestock Prices

Wholesale Meat Prices

Because of the biological time requirements for production, the quarterly output from each livestock group is largely determined by economic conditions existing in previous quarters. To facilitate the estimation of demand relationships, the assumption that quarterly supplies and consumption are equivalent is also made. Although this assumption disregards possible changes in cold storage of meats from period to period, large variations in meat stocks are unusual. Therefore, the hypothesized structure is one in which quarterly production of each meat is placed on the market, unaffected by current prices. The quarterly value for each meat is then determined by the price level required to ration production to consumers throughout the quarter.

The pricing level chosen for this study is the wholesale level. Although retail prices are the ones directly confronting consumers, in the short run consumers tend to be price takers and adjust quantities based on the relative prices of all commodities purchased. Thus, quarterly price variation at the retail level is subject to some degree of rigidity. At the wholesale level quarterly market prices are presumed to be closer to "equilibrium" levels as retail buyers and meat processors bargain in a price discovery process.

According to economic theory of demand the price of a good should be a function of quantity taken and variables which act to shift the demand function, such as income and the prices for substitute goods. This is the basis from which the equation specifications were derived, but because the wholesale pricing level was selected, variables reflecting marketings margins were also considered. Quantities consumed were deflated by population to derive per capita demand. In addition, seasonal factors affecting consumption levels throughout the year were assumed to exert an influence on quarterly demand for each of the meats.

The four quarterly wholesale price equations were estimated with autoregressive two-stage least squares over the 1957-1976 interval. The reported coefficients all carry signs in agreement with economic theory and the statistical fits are fairly high.

$$\underset{}{WFBP} = -1.772 - \underset{(8.35)}{3.586}\ FBEEFPC - \underset{(1.81)}{1.014}\ NFBFSPC + \underset{(.38)}{.049}\ WPP$$

$$+ \underset{(1.03)}{.2622}\ WBP + \underset{(6.34)}{.0454}\ RPCDI + \underset{(.65)}{.408}\ D2 - \underset{(.70)}{.877}\ D3 - \underset{(2.24)}{2.540}\ D4$$

$$R^2 = .9582 \qquad \rho = \underset{(10.52)}{.8483} \qquad DW = 1.80$$

$$UCBP = 2.065 - \underset{(2.85)}{1.183}\ NFBFSPC + \underset{(2.62)}{.2431}\ WFBF + \underset{(2.12)}{.1594}\ WPP + \underset{(1.66)}{.0068}\ RPCDI$$

$$+ \underset{(3.00)}{1.640}\ D2 + \underset{(2.13)}{2.274}\ D3 + \underset{(.47)}{.428}\ D4$$

$$R^2 = .9297 \qquad \rho = \underset{(10.14)}{.786} \qquad DW = 1.85$$

$$WPP = 9.534 - \underset{(6.90)}{4.318}\ PORKSPC + \underset{(1.63)}{.2497}\ WFBP + \underset{(.74)}{.1205}\ UCBP + \underset{(3.64)}{.9160}\ WBP$$

$$+ \underset{(6.50)}{.0216}\ RPCDI + \underset{(1.47)}{15.224}\ MPWR - \underset{(3.44)}{3.807}\ D2 - \underset{(2.84)}{3.951}\ D3 + \underset{(6.40)}{6.454}\ D4$$

$$R^2 = .971 \qquad \rho = \underset{(3.92)}{.505} \qquad DW = 1.88$$

$$
\begin{aligned}
WBP = 4.969 &- \underset{(3.70)}{5.487}\ BROILERSPC + \underset{(.58)}{.0761}\ WFBP + \underset{(1.27)}{.1655}\ UCBP + \underset{(3.13)}{.2321}\ WPP \\
&+ \underset{(1.72)}{.0105}\ RPCDI + \underset{(1.50)}{.1032}\ CPR + \underset{(2.94)}{4.615}\ D2 + \underset{(2.88)}{5.177}\ D3 - \underset{(1.65)}{1.307}\ D4
\end{aligned}
$$

$$
R^2 = .904 \qquad \rho = \underset{(2.12)}{.436} \qquad DW = 1.92
$$

In the equation for wholesale fed beef price, non-fed beef consumption enters as an explanatory variable. Equation specifications which included non-fed beef price as a regressor yielded undesirable results. The coefficient for the non-fed beef price tended to be very large and the sign for pork price became negative. These estimation findings were likely caused by the strong correlation in fed and non-fed beef price and are probably not indicative of true structural relations.

The wholesale non-fed beef price is represented empirically by the price of utility cow beef. Noticeably absent from the equation is the wholesale price of broilers. This variable was tried but was rejected with an estimated negative coefficient. An interesting point is the relative magnitude of the coefficient on income across the four equations. The estimated coefficients imply the demand response to a change in income will be greatest in the fed beef market, all other variables remaining fixed.

The equation for wholesale pork prices includes meat packing wages, intended to represent the costs involved in preparing meat for consumption. Because meat packing wages as a reported series is highly correlated with income, it was first detrended by regressing on a trend variable. The residual series entered the equation as an explanatory variable. The sign of its coefficient demonstrates that wholesale prices tend to be bid upward with increasing processing costs. This same variable was tested in the price equations for beef but did not perform well as an explanatory variable.

The specification of the broiler price equation is similar to the other meats with the exception that the consumer price index is also used as a regressor. Intended to reflect the price of all other commodities, the positive coefficient demonstrates the demand for broilers to be enhanced by a general price rise. This outcome is logical since consumers probably tend to substitute cheaper meats in their diets as budgets become strained by inflation.

Derived Price Relationships

The wholesale price relationships presented in the previous section are determined simultaneously when the quantity of meats produced are cleared from the market place. Prices for animals at lower stages in the production process are presumed to be determined by demand derived from the wholesale level. Under this assumption livestock prices are described as being functionally related to wholesale prices and factors influencing marketing margins in livestock processing.

Slaughter Steer Price

The price of choice slaughter steers is specified to be determined by the current wholesale price of fed beef, wages paid in the meat packing industry, the value of byproducts in beef production and the quantity of slaughter animals being marketed. Meat packing wages should act as a depressant on live animal prices as packers become less willing to bid up the price of the raw product when confronted with production cost increases. Beef by-product is another end use of meat production and should be positively related to the price of slaughter steers. The inclusion of fed marketings as an explanatory variable is intended to test the hypothesis that the margin per unit on animals slaughtered declines as the quantity moving through the market rises. The estimated coefficient supports this hypothesis.

$$SSP = \underset{}{-2.221} + \underset{(41.17)}{.5801}\ WFBP_t - \underset{(2.66)}{.4346}\ MPW_t + \underset{(11.00)}{.6872}\ BBYPRD_t$$

$$+ \underset{(3.27)}{.000246}\ FEDMKTG_t$$

$$R^2 = .995 \qquad DW = 1.82$$

The equation for the price of choice slaughter steers was estimated from quarterly data for the 1957-1976 period. Ordinary least squares is the estimation technique and the R^2 and reported t-values strongly support the hypothesized structure.

Utility Cow Price

The price of utility cows is related to the wholesale price of non-fed beef and the value of beef byproducts. Unlike slaughter steers, however, to obtain cows for slaughter packers must bid the animals away from alternative employment. Cows may either be slaughtered or placed in breeding herds for reproduction. The coefficient for the lagged beef profit variable indicates cow prices are bid higher when the profit potential for cow-calf enterprises improves.

$$UCP = -1.850 + \underset{(21.00)}{.5508}\ UCBP_t + \underset{(1.07)}{.1394}\ BBYPRD_t + \underset{(1.40)}{.8507}\ PROF_{t-1}$$

$$R^2 = .985 \qquad \underset{}{\rho = \underset{(5.89)}{.567}} \qquad DW = 2.01$$

Autoregressive least squares was used to estimate the equation for utility cow price for the sample period 1957-1976. Although the statistics of significance are not as convincing as those in the steer price equation, the signs of the coefficients are acceptable and the fit of the data is good.

Feeder Steer Price

The price of feeder steers entering the feedlot is derived from the value of output from feeding, slaughter steers. Corn price can be used as a proxy for the variable input cost of feeding. The positive coefficient for trend demonstrates a tendency for the price of feeder steers to be bid higher relative to slaughter steers over the observed sample period. This may be caused by improved efficiency in the feeding process. The lagged dependent variable may depict a situation in which the price of feeder steers is not immediately responsive to the market for slaughter animals. The third quarter dummy provides for an adjustment in price during a period of seasonally heavy feeder calf marketings.

$$FSP = -.522 + \underset{(12.11)}{.5768}\ SSP_t - \underset{(10.46)}{2.218}\ CRNP_{t-1} + \underset{(15.16)}{.5895}\ FSP_{t-1}$$

$$+ \underset{(1.11)}{.0116}\ TQ - \underset{(3.48)}{1.152}\ D3$$

$$R^2 = .971 \qquad DW = 1.52$$

Price of Barrows and Gilts

The structure of the price equation for barrows and gilts is similar to those for beef animals. Included as explanatory variables are the current quarter price of pork at wholesale and the value of pork byproducts. Other variables tested in the specification, including meat packing wages and the quantity of pork moving through the market, failed to improve the specification presented.

$$PBG = -4.155 + \underset{(22.41)}{.5476}\, WPP_t + \underset{(1.29)}{.3169}\, PBYPRD_t$$

$$R^2 = .976 \qquad \underset{(4.61)}{\rho = .472} \qquad DW = 1.80$$

The estimation period for the equation is 1957-1976. The technique of estimation is autoregressive least squares. The equation specification is fairly simple but explains a large proportion of the variance in the dependent variable.

Broiler Farm Prices

The farm price of broilers is specified to be related to the wholesale broiler price and wages paid in the poultry processing industry. The estimation technique used is autoregressive least squares. Similar to the estimated relation for hog price, the structure assumed in this equation is simple but apparently offers adequate information to explain the variation in the farm price of broilers.

$$BFP = -.408 + \underset{(62.28)}{.6741}\, WBP_t - \underset{(2.44)}{.7087}\, PDW$$

$$R^2 = .995 \qquad \underset{(11.33)}{\rho = .814} \qquad DW = 2.41$$

With the equations for the farm prices of livestock, the estimation of the parameters for the livestock-feed grain economy is complete. The next two chapters endeavor to validate the model in its entirity and demonstrate its applicability to policy analysis and projection of prices and outputs.

CHAPTER IV

MODEL VALIDATION

The estimated relationships presented in Chapter III were combined into a computerized model capable of making projections of the values of endogenous variables for any number of periods. The purpose of this chapter is to provide information on the performance of the simulation model. Although there are no universally accepted approaches to validation, the methods presented are intended to further substantiate the description of reality given by the estimated form of the model.

Historical Accuracy

Part of the validation process was completed within the parameter estimation framework. The signs of coefficients in individual relations provide a means of testing whether estimation results conform to theoretical expectations. The t-values furnish information on the statistical significance of the estimated parameters. In addition, the computed R^2 offers evidence on the historical tracking ability of separate equations. Although the structural specification is well grounded in the elements of economics and individual relationships are statistically appealing, the overall model may be found lacking in its ability to simulate real-world occurrences. Because most of the equations are estimated separately, the implicit assumptions underlying the complete model could be contradictory. Also, the model is dynamic in that simulation involves the use of lagged endogenous variable values in projections for each period. As the simulation process is repeated for each new time period, forecasting accuracy becomes increasingly dependent on past model performance.

As a measure of the tracking capabilities of the model, two six-year simulation runs were completed. A six-year interval was chosen to be a representative tracking period for intermediate run forecasts. In the first run the model was provided with observed exogenous data and the endogenous values entered as predetermined variables. From this information base the model simulated the time paths of endogenous variables throughout the 1971 to 1976 interval. In the second run, the same time period was considered but projected values of endogenous variables were replaced by values actually observed at the start of each year. Thus, the problem of error compounding would be expected to be less pronounced in the "one-year ahead" simulation run.

Error Analysis of Projections

Tables III and IV present the accuracy results for the two tracking tests of the model. The variables included in the error tables were chosen on the basis of their importance within the livestock-feed grain sector. Because both quarterly and annual observations may be of interest for policy and projection work, selected variables for both periods of reference are reported.

Displayed in the tables are four statistics for the evaluation of simulation errors. Formulas for each of these single-point criteria are given below with 'A' representing the actual value observed, 'P' representing the predicted value and 'n' denoting the number of observations.

TABLE III

ERROR ANALYSIS OF A SIMULATION FOR THE 1971-1976 PERIOD

Endogenous Variable	Absolute Percentage Error	Mean Square Percentage Error	Percentage Bias	Theil U
ANNUAL				
Corn Harvested Acres	2.327	.069	-1.756	.414
Grain Sorghum Harvested Acres	3.112	.143	-.099	.234
Barley Harvested Acres	6.506	.496	-.461	.463
Oats Harvested Acres	5.906	.523	2.441	.685
Feed Grain Harvested Acres	1.763	.049	-.903	.196
Feed Grain Production	5.342	.341	-1.997	.423
Corn Price	8.947	.918	-2.150	.457
Feed Demand	7.308	.624	-2.525	.698
Feed Grain Exports	18.557	4.726	4.508	.819
Ending Stocks	7.417	.746	5.421	.335
Beef Cow Inventory	.643	.010	.605	.247
Breeding Hog Inventory	5.514	.465	-5.514	.561
Choice Slaughter Steer Price	5.363	.363	2.573	.482
Utility Cow Price	8.048	1.215	-2.183	.616
Feeder Steer Price	8.098	.838	5.073	.419
Barrow and Gilt Price	15.534	2.787	-9.499	.822
Broiler Farm Price	14.884	2.803	5.749	.570
QUARTERLY				
Ending Commercial Stocks	5.209	.459	.922	.090
Feed Demand	8.944	1.099	-2.287	.238
Feed Grain Exports	25.416	9.455	8.966	.681
Corn Price	10.987	1.995	-3.610	1.070

TABLE III (Continued)

Endogenous Variable	Absolute Percentage Error	Mean Square Percentage Error	Percentage Bias	Theil U
Placements on Feed	5.313	.516	-.594	.242
Fed Marketings	5.103	.392	-.307	.877
Pig Crop	9.993	1.510	8.023	.436
Fed Beef Production	4.995	.388	-.067	.770
Non-Fed Beef Production	12.086	2.003	-6.696	.779
Pork Production	9.828	1.434	8.416	1.195
Broiler Production	3.798	.234	-.438	.789
Choice Slaughter Steer Price	7.644	.866	2.964	.727
Utility Cow Price	12.004	2.064	-1.303	1.309
Feeder Steer Price	10.658	1.814	5.841	1.134
Barrow and Gilt Price	17.390	4.051	-8.757	1.371
Broiler Farm Price	16.628	3.920	5.970	1.085

TABLE IV

ERROR ANALYSIS OF SIX ONE-YEAR SIMULATIONS FOR THE 1971-1976 PERIOD

Endogenous Variable	Absolute Percentage Error	Mean Square Percentage Error	Percentage Bias	Theil U
ANNUAL				
Corn Harvested Acres	1.114	.016	-.357	.162
Grain Sorghum Harvested Acres	1.973	.086	-.057	.142
Barley Harvested Acres	4.863	.326	-1.464	.328
Oats Harvested Acres	7.293	.621	1.091	.777
Feed Grain Harvested Acres	1.563	.045	-.239	.162
Feed Grain Production	5.650	.503	-.681	.502
Corn Price	8.813	1.502	-2.543	.621
Feed Demand	3.619	.207	-1.956	.315
Feed Grain Exports	9.624	2.245	2.552	.214
Ending Stocks	9.811	1.734	1.717	.460
Beef Cow Inventory	.956	.014	-.184	.299
Breeding Hog Inventory	4.428	.311	-2.712	.330
Choice Slaughter Steer Price	6.047	.564	4.735	.634
Utility Cow Price	8.651	1.079	-1.401	.584
Feeder Steer Price	9.282	1.818	4.875	.652
Barrow and Gilt Price	10.249	1.294	-1.305	.461
Broiler Farm Price	14.084	2.404	6.261	.544
QUARTERLY				
Ending Commercial Stocks	6.040	.800	.564	.104
Feed Demand	5.441	.415	-1.535	.168
Feed Grain Exports	21.295	6.718	6.291	.540
Corn Price	12.977	2.950	-2.974	1.355

TABLE IV (Continued)

Endogenous Variable	Absolute Percentage Error	Mean Square Percentage Error	Percentage Bias	Theil U
Placements on Feed	5.288	.469	.042	.238
Fed Marketings	4.261	.364	.448	.816
Pig Crop	8.283	1.027	3.183	.367
Fed Beef Production	4.347	.362	.667	.722
Non-Fed Beef Production	8.565	1.121	-2.197	.609
Pork Production	5.700	.641	2.475	.830
Broiler Production	3.332	.206	-1.084	.756
Choice Slaughter Steer Price	8.554	1.078	5.184	.816
Utility Cow Price	10.503	2.138	-.515	1.229
Feeder Steer Price	10.628	3.123	5.604	1.485
Barrow and Gilt Price	14.350	2.873	-.085	1.017
Broiler Farm Price	14.781	3.461	6.717	1.084

$$\text{Average Absolute Percentage Error} = \frac{100.0}{n} * \sum_{i=1}^{n} \left| \frac{A_i - P_i}{A_i} \right|$$

$$\text{Percentage Forecast Bias} = \frac{100.0}{n} * \sum_{i=1}^{n} \frac{P_i - A_i}{A_i}$$

$$\text{Mean Square Percentage Error} = \frac{100.0}{n} * \sum_{i=1}^{n} \left(\frac{A_i - P_i}{A_i} \right)^2$$

$$U_2 = \frac{\sqrt{\sum_{i=2}^{n} (A_i - P_i)^2}}{\sqrt{\sum_{i=2}^{n} (A_i - A_{i=1})^2}}$$

The average absolute error is a commonly used measurement of the performance of a model for a given period, and given in percentage form, the units of measurement are inconsequential. The percentage forecast bias allows negative and positive errors to cancel each other within the tracking period but provides a means of determining whether directional bias is a forecasting problem. The mean square percentage error closely resembles the absolute percentage error but tends to penalize single large errors more heavily. The U-statistic formulated by Theil (22) furnishes a means to test the forecasted values against a "no change" extrapolation of the previous period. This error statistic may assume any positive value, with values less than unity representing improvement over the naive model of no change from the previous period.

As shown in the tables, errors are generally smaller for the one-year ahead projections. For both simulations the model attains a fairly high level of accuracy for feed grains. Largest prediction errors tend to occur in feed grain exports which is subject to large random shifts caused by weather and crop conditions in foreign countries. Among the livestock categories the model appears most precise in the forecasting of beef output and cattle prices. An error comparison of the simulated values for quarterly pig crop and pork production indicates the continuous delay simulation model of the market hog sector is performing well. The largest errors in the livestock components tend to be concentrated in price variables. This may be due in part to the relationship between price and market expectations. The actions of market participants cause price to be related to anticipated as well as current market supplies, a phenomenon not easily modeled.

Projection Plots

Displayed in Figures 5 through 12 are plots of predicted and observed values for selected endogenous variables from the simulation run in which only the initial set of lagged endogenous values were given to the model. From the feed grain component of the model Figures 5 and 6 provide plots of annual predicted versus observed values for feed grain harvested acres and ending feed grain stocks, respectively. One of the reasons for the high accuracy in harvested acreage forecasts is the heavy reliance on exogenous input data for projection of feed grain supply. Principal variables in the harvested acreage equations are those related to government policy, and since these variables are totally exogenous, error compounding is not a serious problem. The ending year stock demand for feed grains includes both government and commercial stocks. Although the model tracks the pattern of reported stocks rather well, the forecasts for the last four years are biased upward.

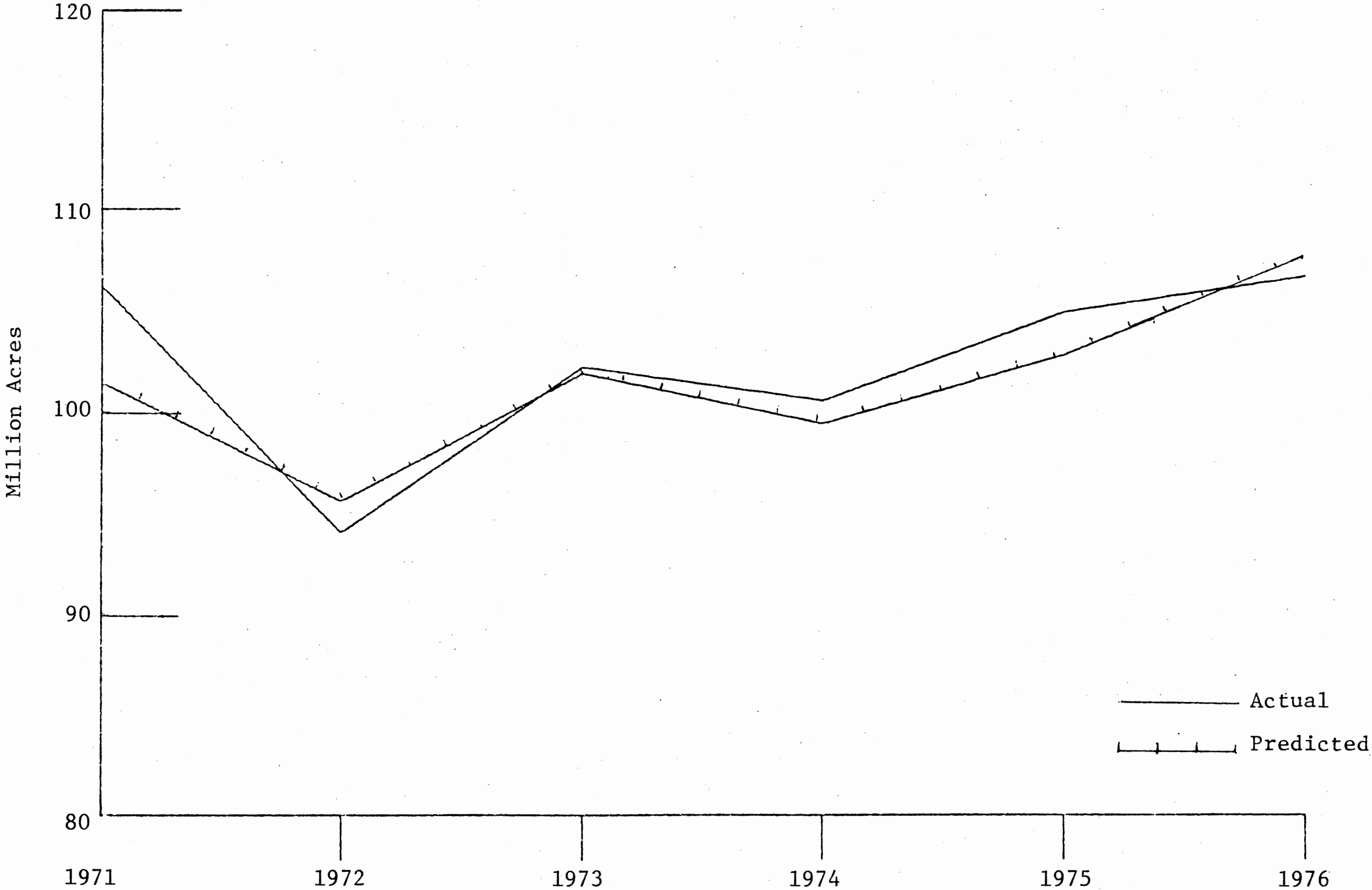

Figure 5. Predicted Versus Actual Annual Feed Grain Harvested Acres, 1971-1976

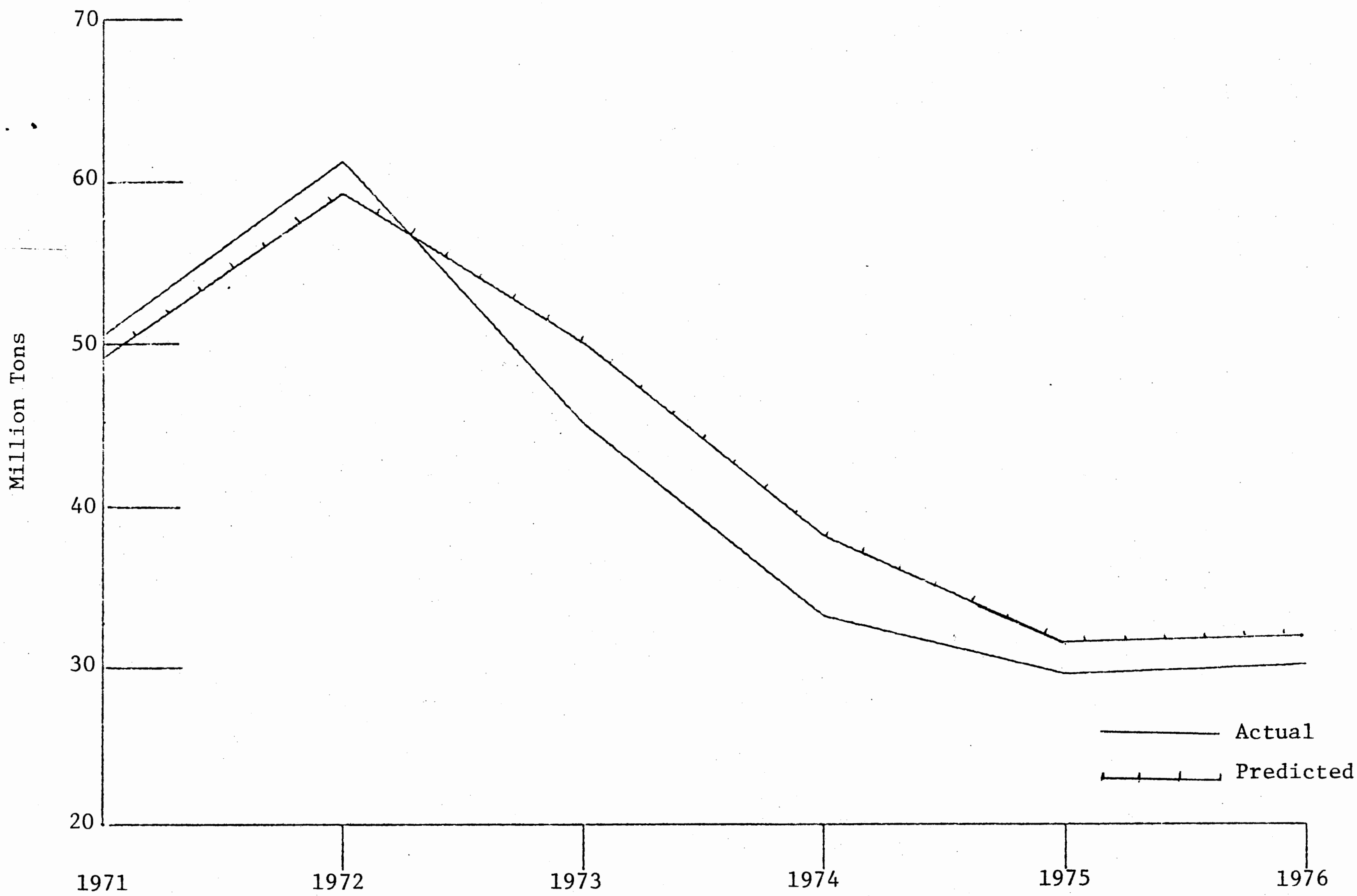

Figure 6. Predicted Versus Actual Ending Year Feed Grain Stocks, 1971-1976

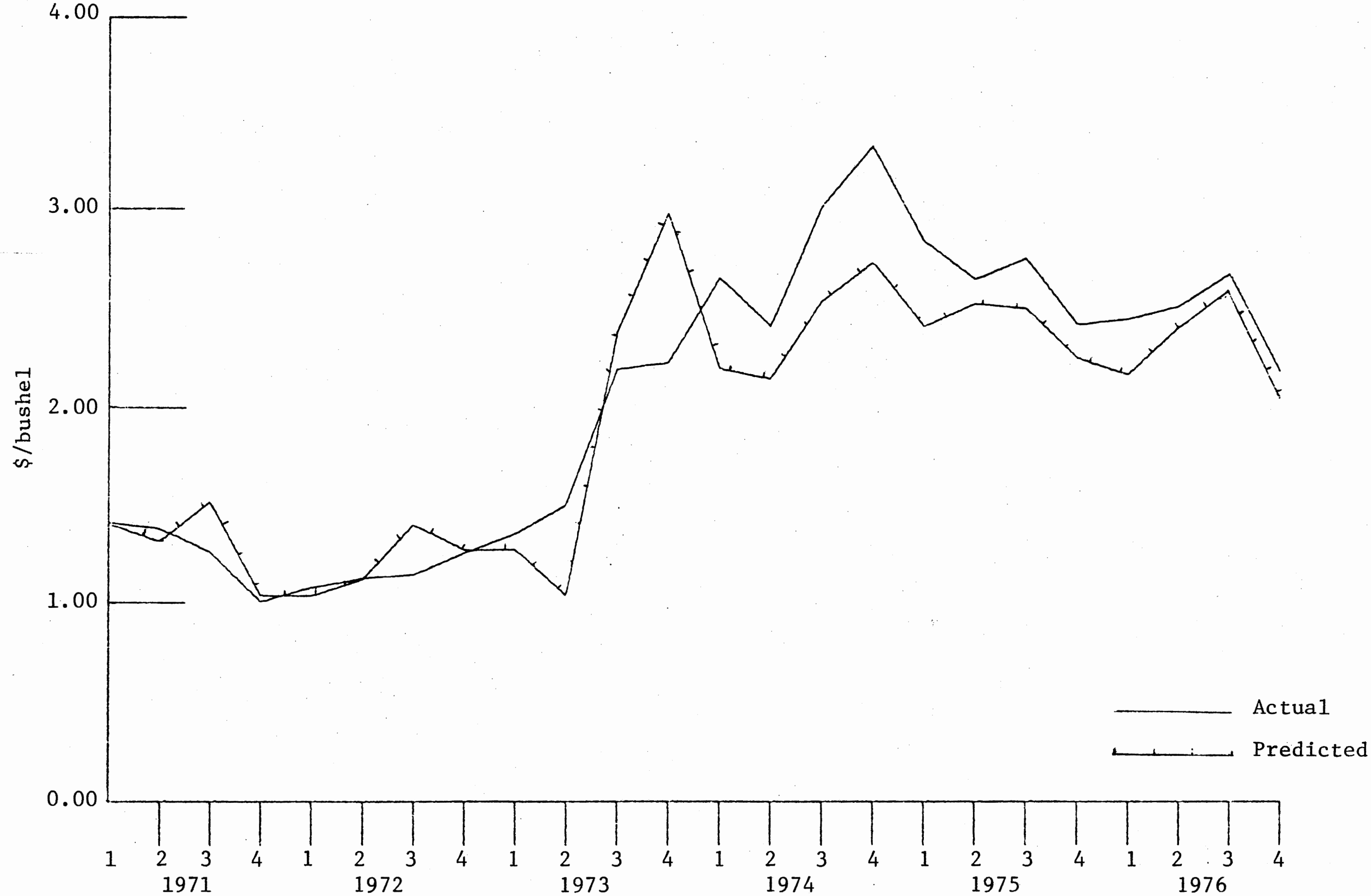

Figure 7. Predicted Versus Actual Quarterly Corn Price, 1971-1976

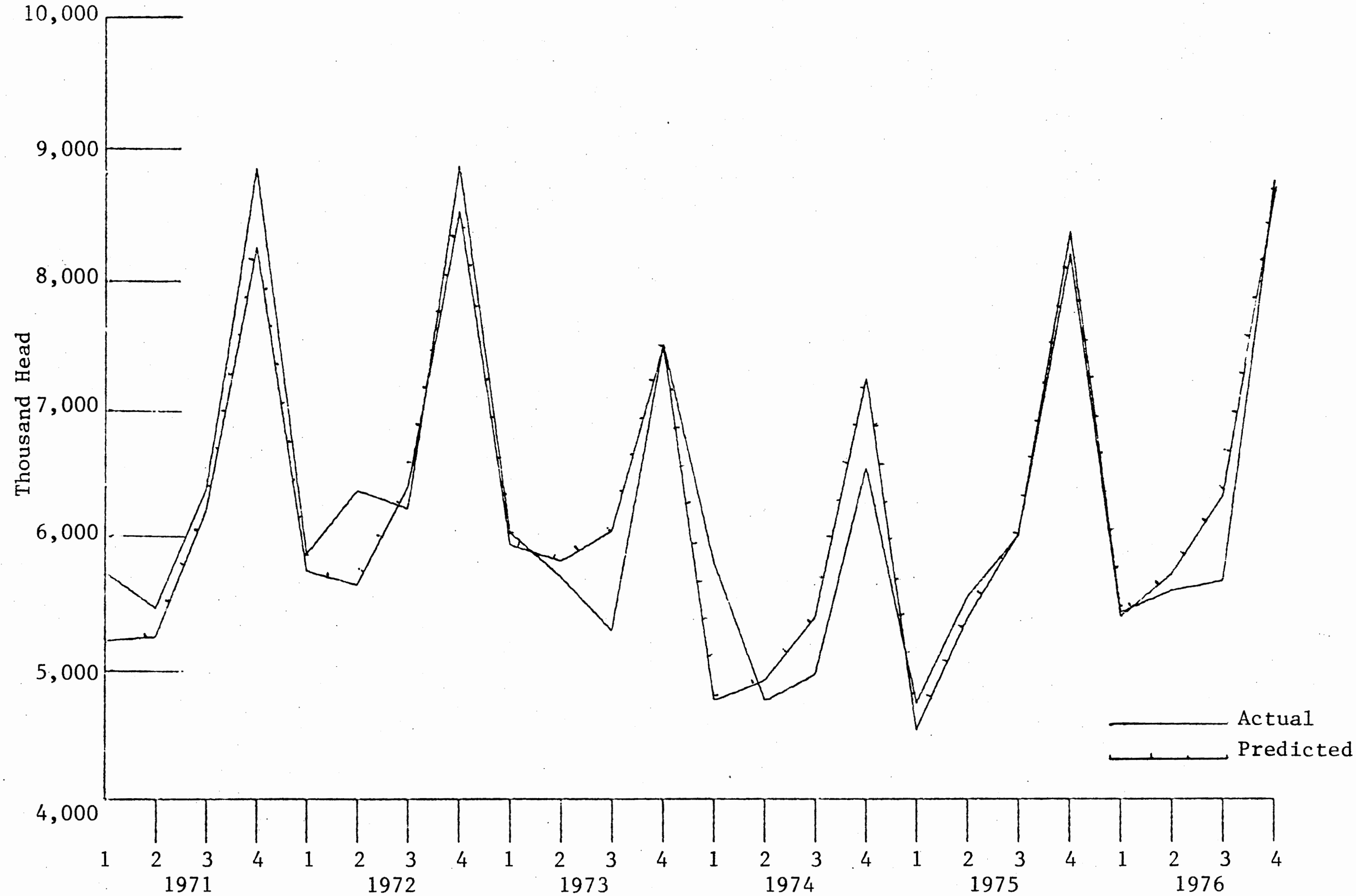

Figure 8. Predicted Versus Actual Quarterly Placements of Cattle on Feed in 23 States, 1971-1976

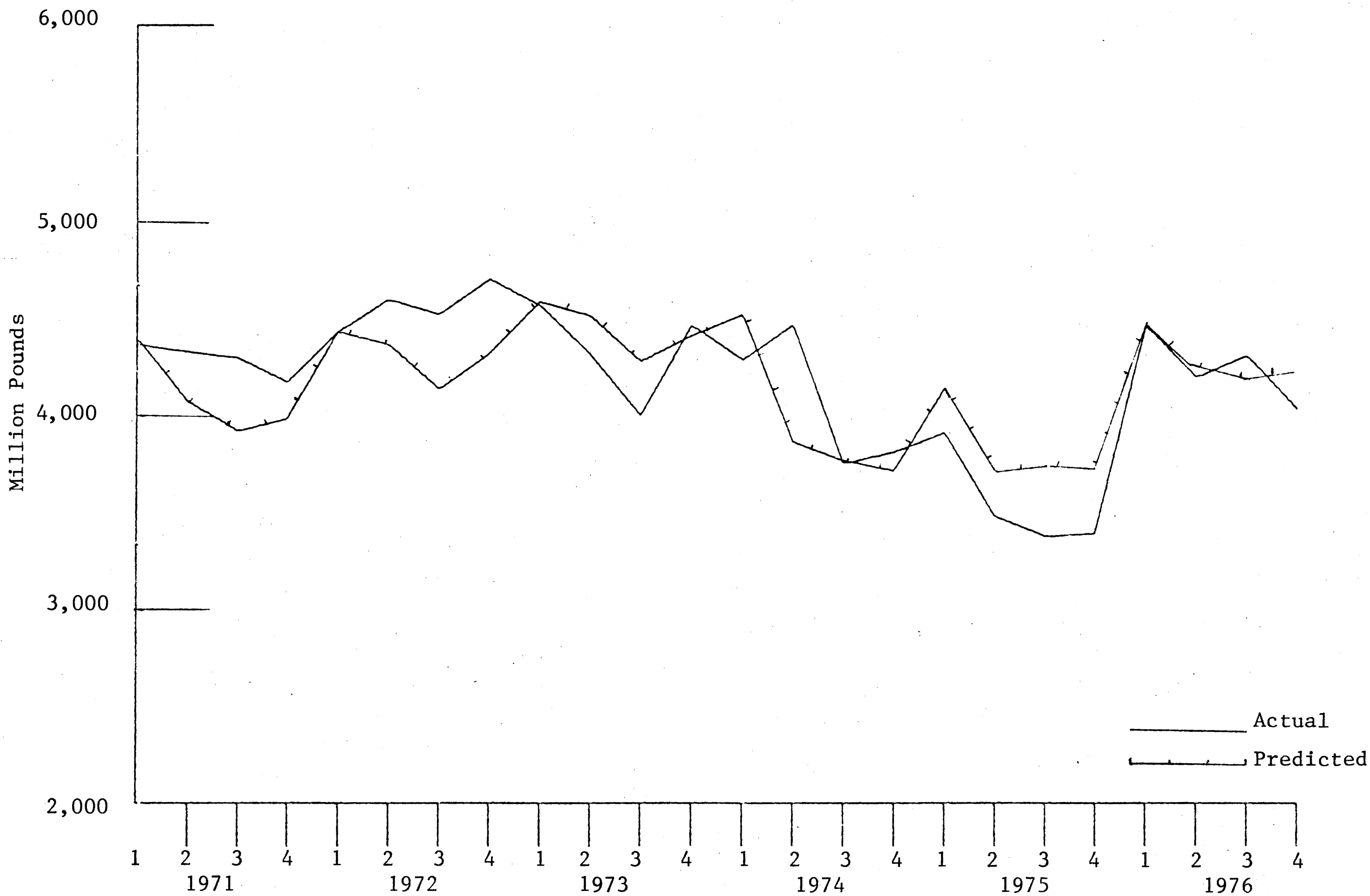

Figure 9. Predicted Versus Actual Quarterly Fed Beef Production, 1971-1976

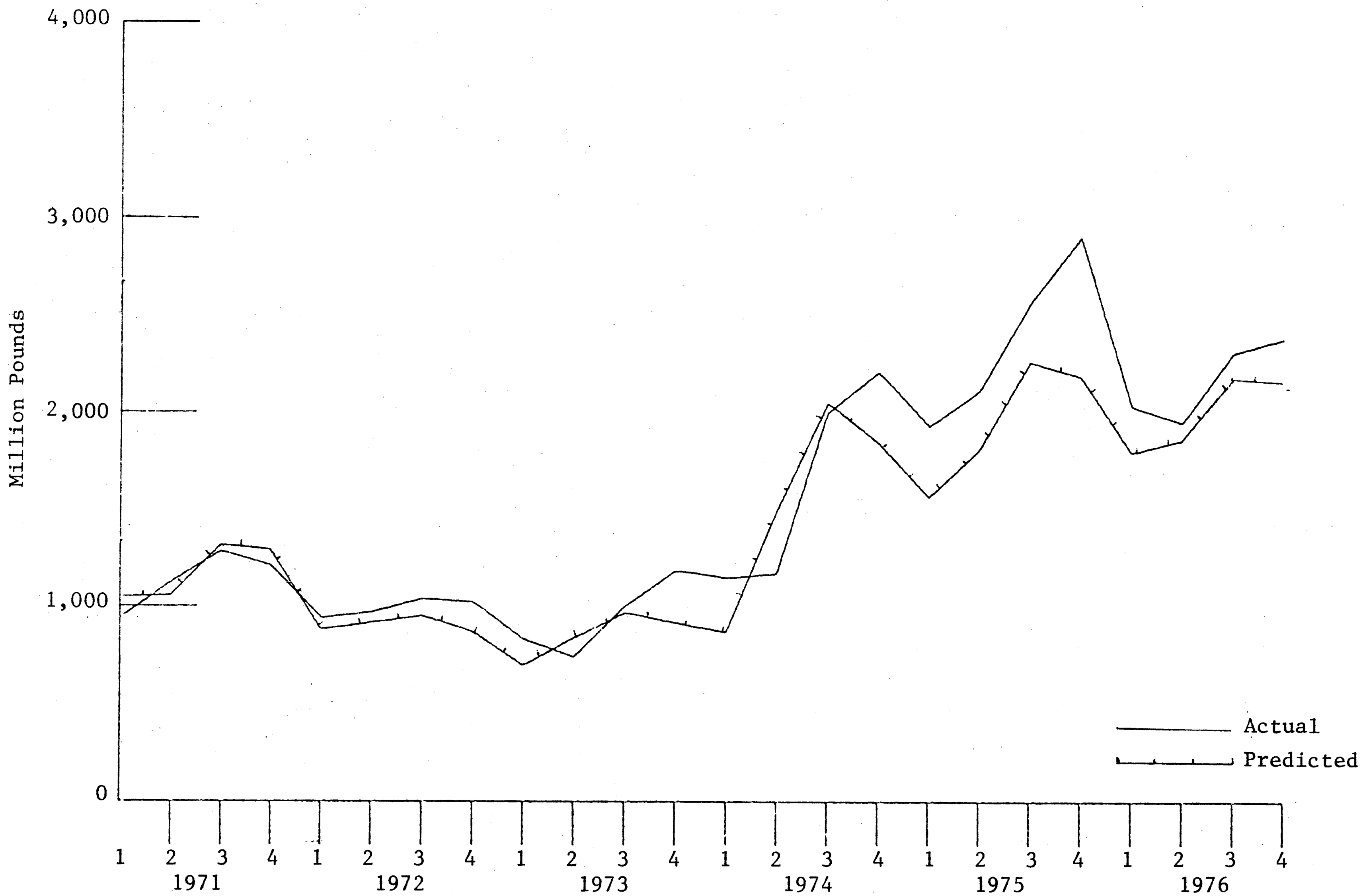

Figure 10. Predicted Versus Actual Quarterly Non-Fed Beef Production, 1971-1976

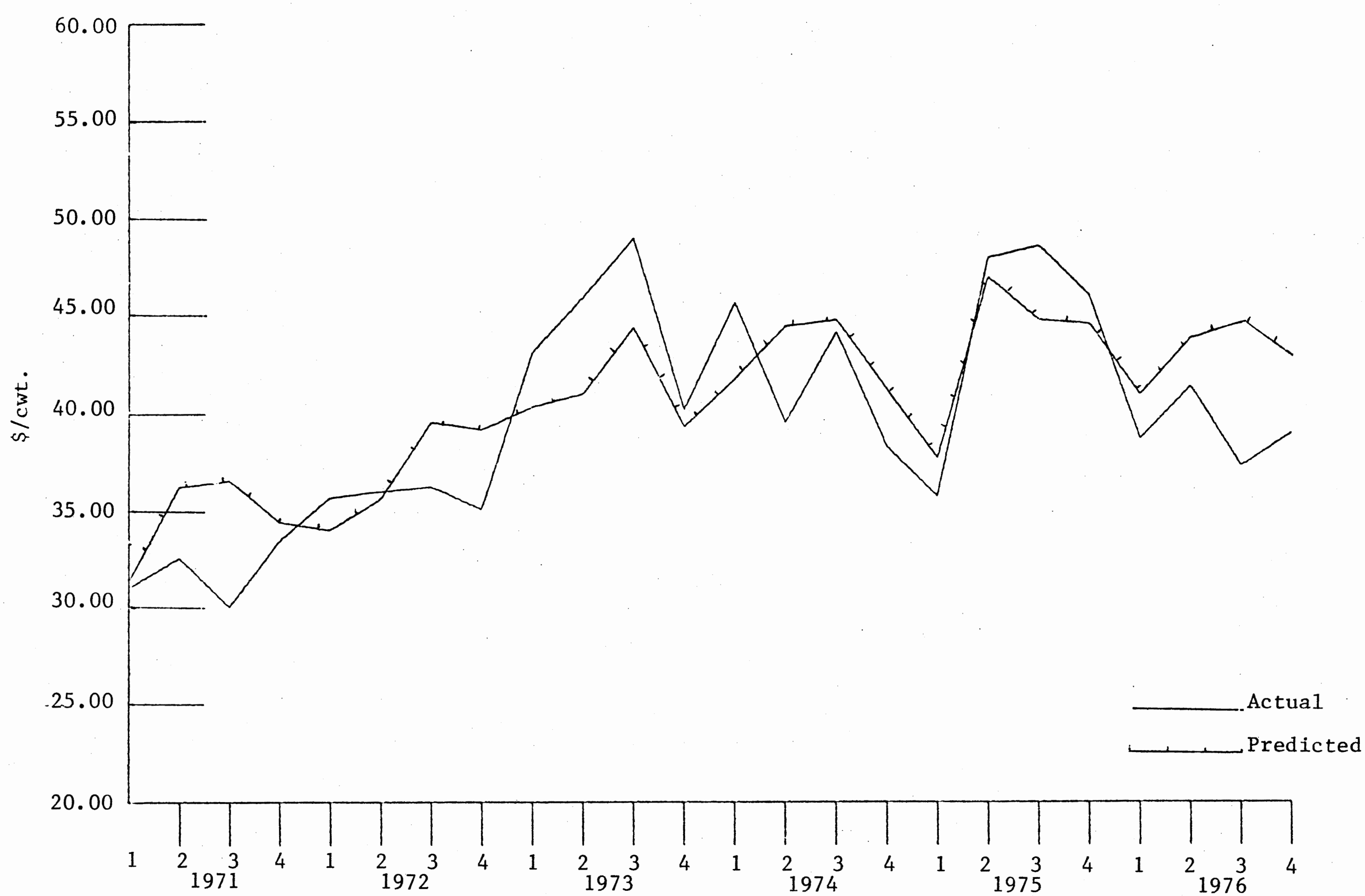

Figure 11. Predicted Versus Actual Quarterly Choice Slaughter Steer Price, 1971-1976

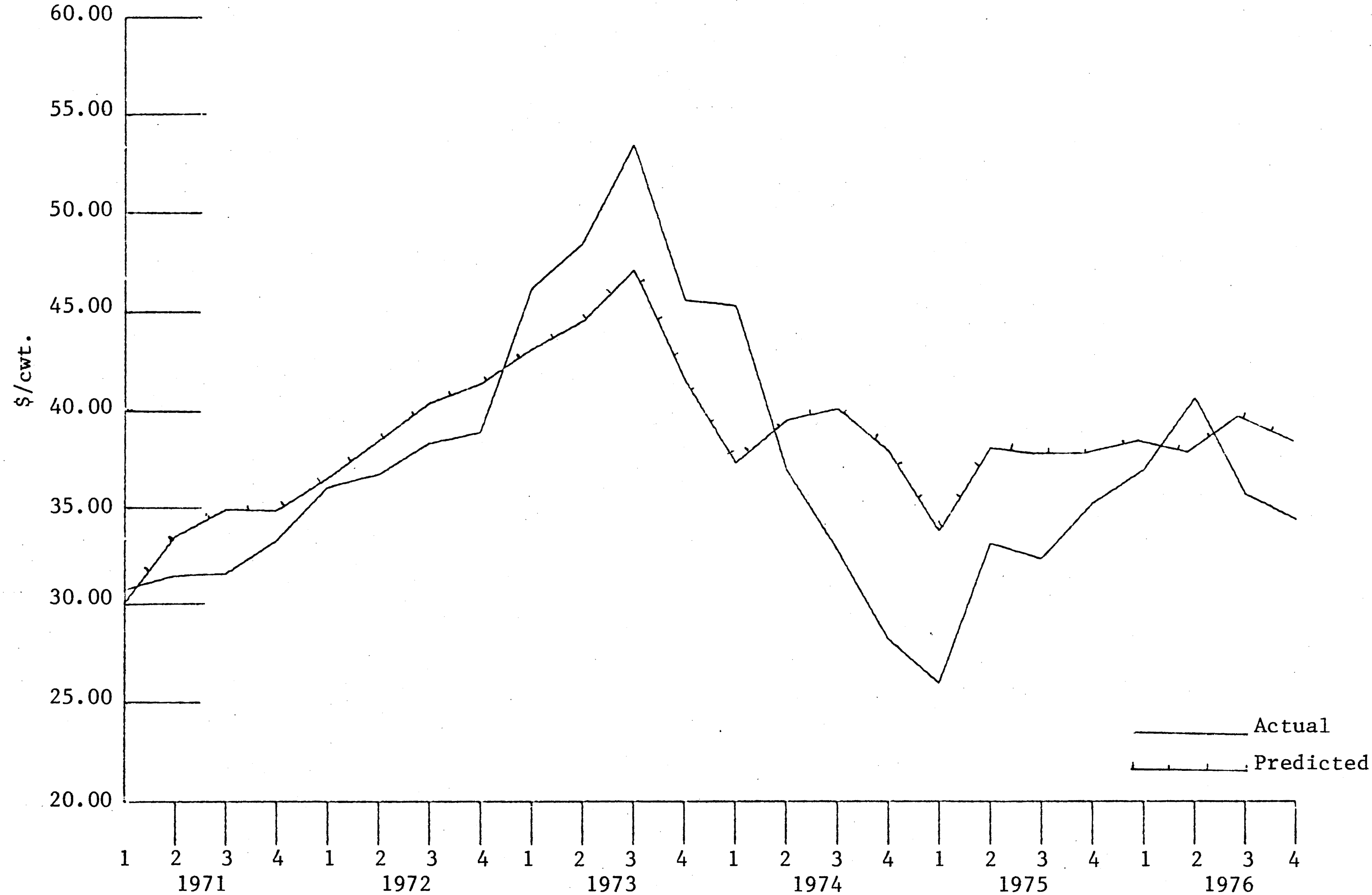

Figure 12. Predicted Versus Actual Quarterly Feeder Steer Price, 1971-1976

Figure 7 shows the quarterly forecasting accuracy for corn price. Again, the basic pattern of the observed data compare closely to the simulated pattern, but the model consistently underestimates price in the final twelve quarters. Had the model produced lower projected values for ending stocks in the last three years, apparently the bias in predicted values for corn price would also have decreased.

The tracking results for five endogenous variables from the livestock component are presented in Figures 8 through 12. Placements of cattle on feed are shown to be highly seasonal in Figure 8. Directional bias for projections of this variable is not as obvious as for corn price or stocks. The results of fed beef projections given in Figure 9 demonstrate the model is simulating major turning points fairly well. The downward bias in the first few years is linked to the errors in placement forecasts for the same interval. The plot of simulated and actual nonfed beef production is presented in Figure 10. The model also provides accurate information on the turning points for this endogenous variable over the observed series.

Figures 11 and 12 display the forecast errors for choice slaughter steer and feeder steer price. Even though the model does an acceptable job of forecasting both of these variables, the tendency to underestimate peaks and overestimate observed lows is clearly evident. This outcome may be attributed in part to the time period of simulation. The variance in livestock prices between the years 1971 and 1976 is unusually large compared to that for previous years included in the estimation.

Dynamic Characteristics

Because the model is dynamic in the sense that previously determined endogenous variable values are utilized in generating current period projections, validation becomes more complex than simply comparing model results to observed data. If the model is to be a reliable representation of real world markets, its dynamic behavior should closely resemble the observed behavior of markets. More explicitly, commodity markets are expected to gravitate toward equilibrium levels in response to economic stimuli. Dynamic stability thus becomes an important consideration in model validation.

As Labys (12) points out, simulation provides a method to examine the time paths of endogenous variables and determine whether covergence is achieved. From a given set of values for lagged endogenous variables and the set of exogenous variables held at a fixed level, a stable model should generate endogenous values which either converge to stable values or oscillate in a non-divergent pattern.

Labys also indicates that the simulation approach for testing stability may not offer conclusive proof. A nonlinear model can display stable characteristics when simulating under one set of exogenous conditions but be unstable under a different scenario. This possibility is easily understood in the case of the familiar cobweb model where quantity demanded for a period depends on the price for that period, but quantity supplied is assumed to be determined by price in the previous period. With linear demand and supply functions, the only requirement for model stability is for the supply curve to be more steeply sloped than the demand curve. If either the demand or supply function is nonlinear, the lagged starting value of price becomes a factor in considering whether the model is capable of moving to an equilibrium level.

Because the model for this study contains both linear and nonlinear functions, its stability characteristics are difficult to fully examine. The approach taken was one of using the model to simulate for a number of periods with various starting conditions, holding exogenous values constant at initial levels. This technique simply furnishes a means of testing whether the generated time paths of endogenous variables appear reasonable in view of existing knowledge on grain and livestock markets.

The model was given starting values for several years and allowed to generate endogenous values for 25 year periods. Selected results from this portion of the model validation are displayed in Figures 13, 14, and 15. The variables associated directly with grain markets in the conducted simulations always appeared to gravitate toward equilibrium levels after a period of adjustment. Figure 13 which traces the adjustment process in feed grain production from the starting value for 1976, is indicative of all the results obtained for the feed grain component of the model.

The outcomes of stability tests for the livestock sectors were mixed. In particular, results appeared to be extremely sensitive to starting conditions. Figures 14 and 15 show the time paths for beef and pork production for two 25 year periods beginning in 1971 and 1976, respectively. Although these variables do not appear explosive over the interval, the amplitude in beef production for the 1971 starting values may be widening through time. The cyclical nature of beef production is also more pronounced than that for pork. Although some evidence of a pork cycle is generated in both runs, beef appears to be a

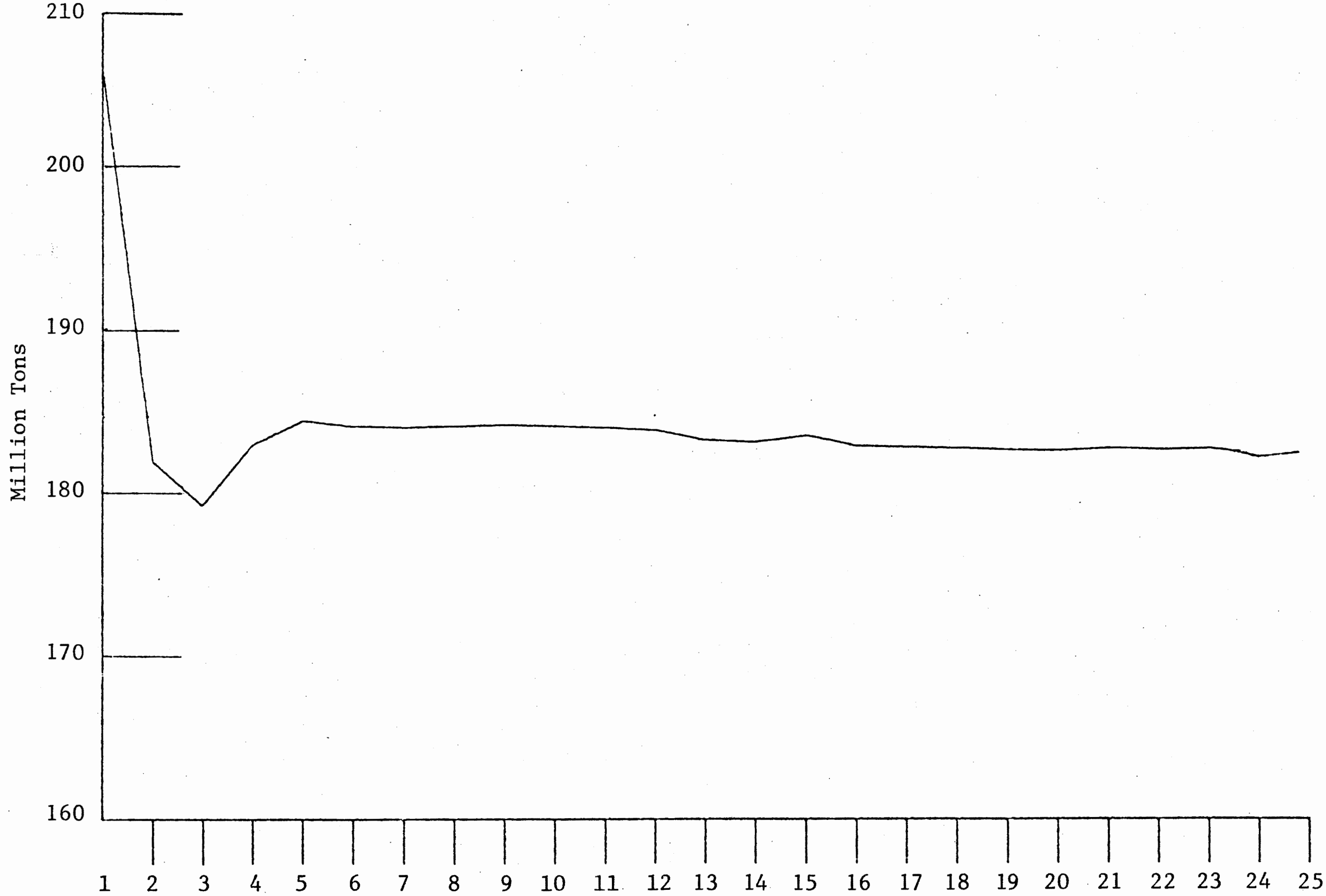

Figure 13. Feed Grain Production Simulated for 25 Years Holding Exogenous Variables Constant at 1976 Levels

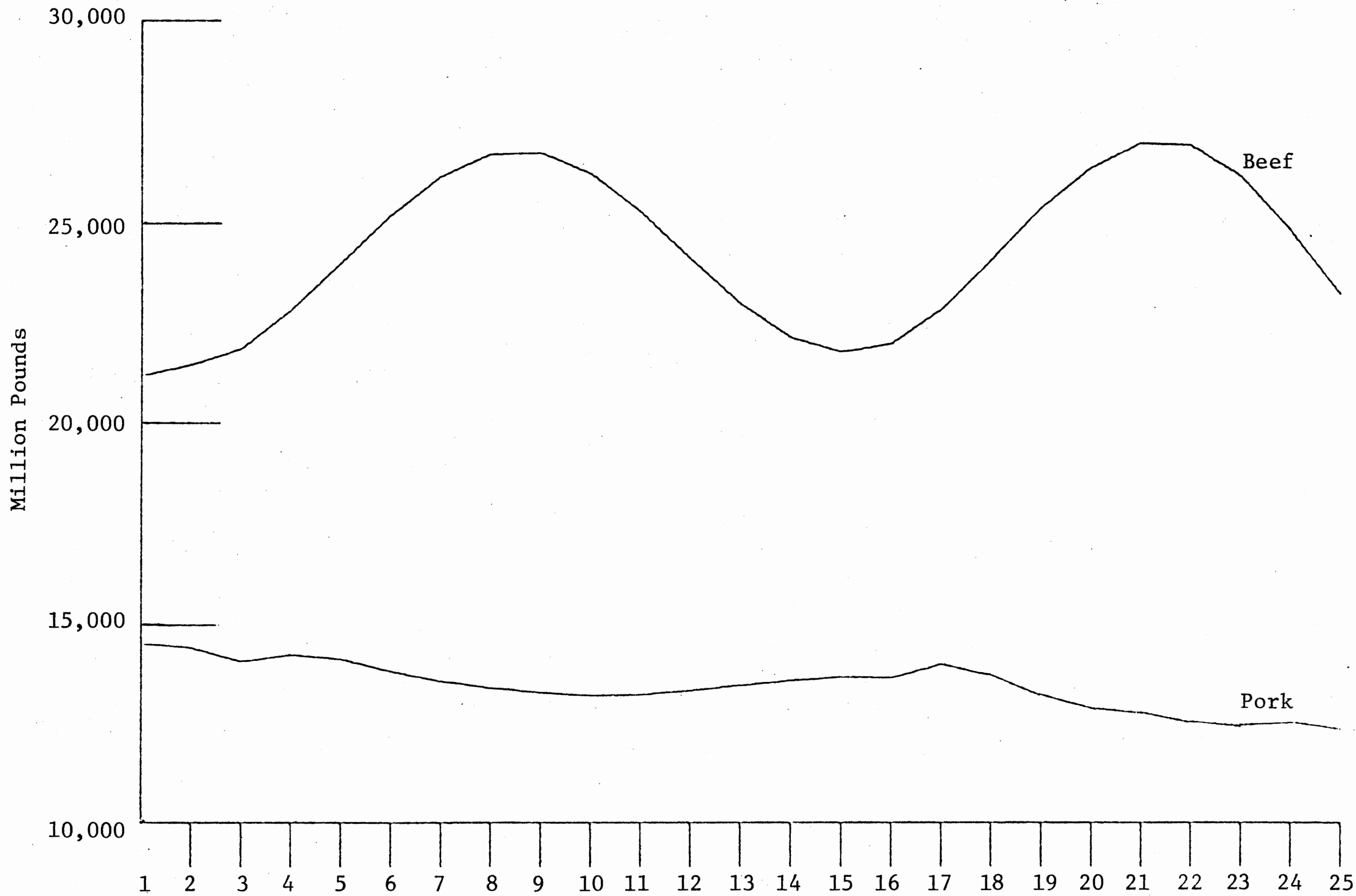

Figure 14. Beef and Pork Production Simulated for 25 Years Holding Exogenous Variables Constant at 1976 Levels

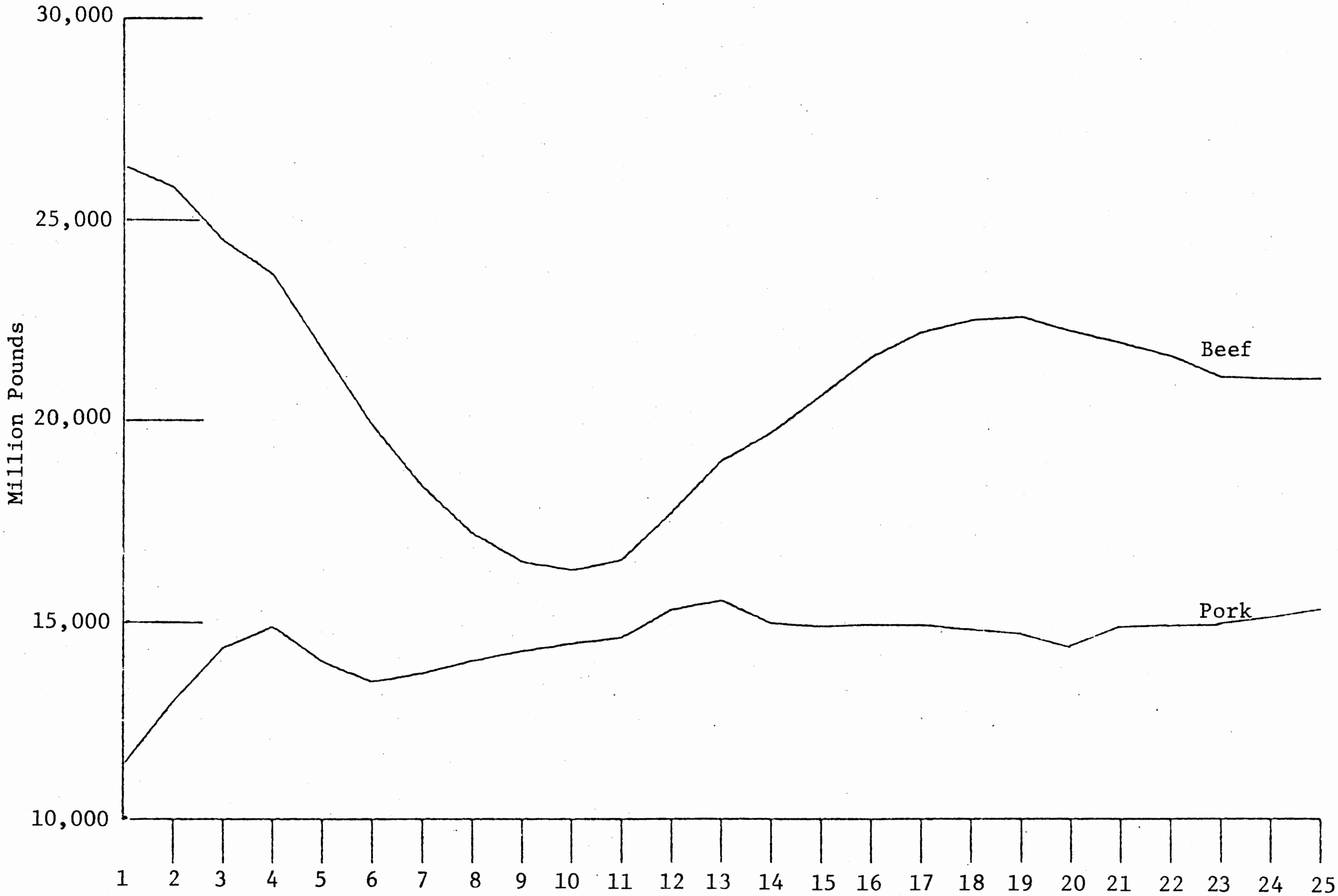

Figure 15. Beef and Pork Production Simulated for 25 Years Holding Exogenous Variables Constant at 1976 Levels

dominant influence on pork output. As the initial shocks of beginning variable values are dampened through several periods of simulation, the time path of pork production seems to be inversely related to that for beef. Although the beef and pork markets do interact, this one-way dominance is not recognized as a real-world occurrence. In the structure of the model, beef and pork price are related at the wholesale level. Attempts to reduce the controlling influence of beef within the model by respecifying wholesale price relationships were unsuccessful.

Although the strong influence of the beef market on pork output within the model is not desirable, a noteworthy fact is that several periods of simulation are necessary before the relationship is recognizable. Thus, results generated by the model for periods of up to ten years might seem more reliable than long run simulated output.

The beef cycles generated in simulation runs by holding exogenous variables constant were generally greater than ten years in length. This result conforms to what is generally considered the observed cycle length in cattle numbers. Within the model the relationship exercising primary control over the nature of the cycle generated for cattle numbers is the beef cow inventory. Although the beef cycle produced by the inventory equation for the 1971 starting values may be diverging slightly, the equation initially specified and estimated for beef cows was extremely explosive. The original relationship contained five forms of the beef profit variable, lagged from one to five years. This specification fitted the observed data better than the reported equation but caused the model to generate unrealistically low and high projections of endogenous variables after approximately ten years. Thus, there appears to be some trade-offs involved between historical tracking and stability characteristics of the model.

Any firm conclusions drawn from the validation procedures conducted would be subject to some dispute. The prediction errors for the 1971-1976 period tend to support the description of livestock and feed grain markets offered by the model. The portion of the model representing the feed grain markets also exhibits stable properties in the simulation tests conducted. The livestock sectors within the model did not perform as well when examined for dynamic stability and cyclical production characteristics. Given the results presented, however, an argument can be made for the ability of the livestock models to approximate reality over the short and intermediate runs.

CHAPTER V

MODEL APPLICATION FOR POLICY AND PROJECTION

The intended purpose for the livestock feed grain model is the analysis of policy proposals and short and intermediate run projections of endogenous variable values. As such, this chapter is divided into two sections. The first deals with hypothesized changes in exogenous variables and the resulting measured impacts on output variables of the model. The second section reports five-year projected values for endogenous variables based on a specific set of assumed exogenous conditions.

Estimated Impacts of Changes in Exogenous Variables

One approach to gaining a general understanding of the sensitivity of endogenous elements of a model to exogenous variable values is through the use of multiplier analysis. Several forms of multipliers may be used, but the one considered most applicable to policy analysis is the dynamic multiplier measuring the change in future endogenous values caused by a sustained change in one or more of the assumed exogenous conditions. This form of multiplier may be defined as:

$$M_i = \frac{\Delta Y_{t+i}}{\Delta X_t}$$

where Y_{t+i} is the value of the endogenous variable observed i periods hence and X_t is the exogenous variable for which the change is held constant for period t through t+i.

A concept closely related to multiplier analysis and more familiar to most economists is that of elasticities. However, the two ideas differ in one primary respect. An elasticity is usually defined as the change in one variable caused by a change in another variable holding all things constant. Multipliers derived from a dynamic model assume only other factors exogenous to the model to be held constant. Endogenous variables are allowed to interact and affect the measured response given by estimated multipliers.

If all the relationships within a model are specified to be linear and certain stability conditions are met, multipliers may be derived mathematically. Labys (12) provides a thorough discussion of the necessary tests for stability and the mathematical formulations of multipliers for linear models. Another approach must be used if non-linearities are present as is the case with the model reported here. With simulation techniques exogenous variables may be held at constant values as endogenous variables are generated repeatedly. When all endogenous variables cease to change from successive solutions, the model is termed to be in "steady state". At this point one or more of the exogenous variables may be changed and held constant at a new level. Simulated changes in endogenous variables determined in this manner are equivalent to those derived mathematically.

A problem is encountered in developing multipliers through simulation if one or more of the endogenous variables continues to change in repetitive solutions. In the model described here, variables associated with the beef and pork sectors do not reach stable levels, but continue to vary as a cyclical supply response is generated. Multipliers derived by exogenous shifts at any point in time are thus conditioned by initial variable values and will vary depending on the starting levels for endogenous variables.

Given the conflict between necessary conditions for multiplier development and the circumstances for this model, multipliers as defined could not be obtained. An alternative approach was devised to estimate the impact of exogenous shifts to allow an analysis of policy proposals. Two recent years, 1971 and 1976, were chosen as starting periods for impact simulations. A 15 year simulation from both starting points was then completed, holding all variables exogenous to the model constant at initial levels. As comparison, specific exogenous variables were given new starting values and the 15 year simulations were repeated. Endogenous impacts for each variation in exogenous conditions were then calculated by subtracting base values of endogenous variables (taken from initial simulations) from the new simulated values. The impact values obtained in this way differ from dynamic multipliers in that a "steady state" was not the starting point for the simulation.

Trapp (23) argues that impacts quantified by this method may be more meaningful for policy analysis than dynamic multipliers. His contention is that a "steady state" exemplifies only one set of starting conditions and this situation is probably never observed in reality as exogenous factors continually change and force adjustments within an economic subsector. If this idea has merit, multipliers may not provide the best estimate of anticipated endogenous changes in all cases.

An improved approach might be to derive impact estimates from a period in which a similar set of initial conditions were known to be present.

The two periods taken as starting points for the study of impacts on endogenous variables were chosen because of the degree of contrast displayed in initial conditions. In 1971 cattle inventories were beginning to grow more rapidly following a cyclical low in 1967. Hog prices were very low as hog numbers peaked and were on a decline. Grain prices were generally low and near the loan rate as the government was heavily involved in agricultural markets. In 1976 cattle inventories were in a period of decline. Hog prices were extremely high as hog inventories reached a bottom. In addition, grain prices were high in comparison to 1971 levels and the government programs essentially had no impact on the markets. The purpose of using two periods so diverse to derive impact responses is an effort to estimate a range for the changes in each endogenous variable which might reasonably be expected.

The estimated impacts of exogenous shifts on selected endogenous variables are given in Tables V through X. To facilitate interpretation, the impacts are given in the form of index numbers. For example, an index of 102.00 means the change in factors exogenous to the model caused a two percent increase in the simulated endogenous variable value for that time period. As a point of reference for physical quantities, the unit of measurement is given below each endogenous variable. Also listed are the observed endogenous variable values for 1971 and 1976, respectively, to allow the interested reader to convert percentage changes to absolute changes. For each of the exogenous changes considered, estimated annual impacts are given for the first five years, the tenth year and the fifteenth. Considering the long run dynamic characteristics of the model, the results for the first five years are probably most reliable.

Impacts of Income Change

Table V displays the results of a one percent increase in per capita disposable income. Disposable income enters the model as an influence on wholesale meat prices and domestic food demand for feed grains. Little response is initially seen in the grain markets as income affects total feed demand only slightly. More noticeable short run impacts are realized in meat and livestock markets with income being a significant shift variable for meat demand. An interesting development lies in the relative increases in the prices for slaughter steers and hogs. Although the estimated structural coefficient on income for wholesale beef price is larger than that for pork, the derived reduced form coefficient is not. The income elasticities computed at the mean from the structural coefficients are 1.83 for fed beef and .860 for pork. The first period impact multiplier for income given by the reduced form coefficient is .075 for wholesale pork price compared to .059 for fed beef. This switch in relative magnitudes is caused by the result of the estimated cross price relationship between beef and pork at the wholesale level. Wholesale fed beef price has a large structural income coefficient and carries a strong impact on pork price. Conversely, pork has a smaller structural coefficient and has a smaller estimated impact of fed beef price.

TABLE V

ESTIMATED IMPACTS OF A ONE PERCENT INCREASE IN DISPOSABLE INCOME

Endogenous Variable		Years 1	2	3	4	5	10	15
Corn Harvested Acres	1971	100.00	100.08	100.10	100.07	100.05	100.25	100.50
(64.1, 71.1 Mil. Acres)	1976	100.00	100.05	100.11	100.12	100.11	100.14	100.22
Feed Grain Harvested Acres	1971	100.00	100.02	100.03	100.02	99.99	100.07	100.17
(106.3, 106.8 Mil. Acres)	1976	100.00	100.00	100.03	100.03	100.03	100.03	100.05
Feed Grain Production	1971	100.00	100.04	100.06	100.04	100.01	100.15	100.33
(207.8, 212.3 Mil. Tons)	1976	100.00	100.02	100.07	100.07	100.07	100.08	100.13
Corn Price	1971	100.90	100.46	100.85	100.67	100.86	104.19	105.72
(1.27, 2.49 $/bu.)	1976	100.78	100.58	101.53	101.46	101.39	101.95	103.16
Feed Demand	1971	100.33	100.51	100.52	100.46	100.51	100.60	100.74
(143.4, 126.0 Mil. Tons)	1976	100.31	100.19	100.26	100.25	100.22	100.39	100.66
Feed Grain Exports	1971	99.54	99.35	99.68	99.74	99.71	98.21	96.69
(19.1, 57.0 Mil. Tons)	1976	99.65	98.89	98.87	98.92	98.98	98.62	97.99
Ending Feed Gr. Stocks	1971	99.69	98.51	97.79	97.11	96.42	93.13	91.91
(50.4, 29.9 Mil. Tons)	1976	99.47	99.00	98.72	98.67	98.76	98.53	97.83
Fed Beef Production	1971	100.07	100.50	100.61	100.98	101.47	102.03	99.42
(17151, 16993 Mil. Lbs.)	1976	100.05	100.24	100.29	100.55	100.99	102.89	101.71
Non-Fed Beef Production	1971	98.16	95.39	96.36	97.96	99.82	104.09	97.03
(4547, 8673 Mil. Lbs.)	1976	99.39	98.66	99.01	99.59	100.32	104.66	103.18

TABLE V (Continued)

Endogenous Variable		Years 1	2	3	4	5	10	15
Pork Production	1971	100.08	100.92	101.51	101.37	101.12	99.69	100.39
(14606, 12218 Mil. Lbs.)	1976	100.08	100.44	100.74	100.84	100.89	100.01	99.65
Slaughter Steer Price	1971	103.00	102.68	102.35	101.73	100.66	98.86	104.42
(32.42, 39.11 $/cwt.)	1976	102.59	102.61	102.27	101.82	101.29	100.01	100.67
Feeder Steer Price	1971	102.87	103.17	102.95	102.36	101.21	96.44	103.77
(31.83, 36.93 $/cwt.)	1976	102.86	102.96	102.75	102.24	101.48	99.41	99.69
Barrow-Gilt Price	1971	105.10	102.85	100.99	100.86	100.73	103.29	105.42
(18.57, 43.83 $/cwt.)	1976	102.83	103.08	102.44	102.01	101.56	101.81	103.09

Impacts of an Increase in the General Price Level

In Table VI are listed the estimated impacts for a two percent increase in the level of prices exogenous to the model. Exogenous factors measuring the general price level which enter the model are the consumer price index, the index of prices paid by farmers for production inputs and the index of prices paid for farm machinery. To simulate the change, all of these indices were increased by two percent. The CPI enters the wholesale meat price equations and feed grain demand equation as a deflator of disposable income. An increase in all other prices acts as a depressant on real income and the short run effect is large for derived livestock prices.

The index of prices paid by farmers is used to calculate the costs of cow-calf operations and as a deflator of price variables entering acreage equations. One unexpected outcome of the simulation is the resulting increase in feed grain acreage. This direction of response occurs as consequence of the adjustment made in the prices paid index based on expected yields. Feed grains have demonstrated larger yield increases since the 1950's than competitive crops such as soybeans, wheat and cotton. This has the effect of causing comparable increased input costs per acre to be spread over a larger number of units of output for the feed grains. Total output of feed grains does decline, however, as farmers are less inclined to use practices which expand yields at the expense of increased variable costs. The price of corn falls even though production is reduced because the largest response to the higher price level in the feed grain market comes in form of reduced demand for livestock feeds.

TABLE VI

ESTIMATED IMPACTS OF A TWO PERCENT INCREASE IN INFLATION

Endogenous Variable		Years						
		1	2	3	4	5	10	15
Corn Harvested Acres	1971	100.54	100.44	100.46	100.61	100.65	100.60	99.70
(64.1, 71.1 Mil. Acres)	1976	100.20	100.36	100.36	100.20	100.17	100.14	99.97
Feed Grain Harvested Acres	1971	100.46	100.49	100.47	100.43	100.49	100.51	100.21
(106.3, 106.8 Mil. Acres)	1976	100.27	100.52	100.50	100.43	100.41	100.40	100.36
Feed Grain Production	1971	99.99	99.90	99.85	99.81	99.85	99.80	99.22
(207.8, 212.3 Mil. Tons)	1976	99.80	99.98	99.92	99.77	99.74	99.70	99.61
Corn Price	1971	98.27	97.45	98.49	98.67	98.56	93.72	88.32
(1.27, 2.49 $/bu.)	1976	98.96	97.00	97.18	97.41	97.64	96.47	93.64
Feed Demand	1971	99.41	99.01	99.01	99.09	98.96	98.61	98.31
(143.4, 126.0 Mil. Tons)	1976	99.45	99.50	99.55	99.61	99.53	99.08	98.44
Feed Grain Exports	1971	100.87	101.14	100.57	100.49	100.54	102.74	106.39
(19.1, 57.0 Mil. Tons)	1976	100.44	102.14	102.01	101.85	101.75	102.49	104.05
Ending Feed Grain Stocks	1971	100.67	102.95	104.26	105.51	106.60	113.78	121.04
(50.4, 29.9 Mil. Tons)	1976	101.26	101.93	102.29	102.57	102.27	102.57	104.25
Fed Beef Production	1971	99.85	99.02	98.78	97.95	96.88	95.60	100.78
(17151, 16993 Mil. Lbs.)	1976	99.92	99.24	99.34	98.79	97.80	93.71	96.31
Non-Fed Beef Production	1971	103.73	109.45	107.49	103.98	99.83	91.43	105.52
(4547, 8673 Mil. Lbs.)	1976	101.24	102.96	101.84	100.71	99.38	90.82	94.24

TABLE VI (Continued)

Endogenous Variable		Years 1	2	3	4	5	10	15
Pork Production	1971	99.88	98.28	97.20	97.46	98.05	100.59	99.48
(14606, 12218 Mil. Lbs.)	1976	99.82	98.67	98.32	98.30	98.45	100.24	101.18
Slaughter Steer Price	1971	94.25	94.85	95.49	96.96	99.35	103.48	92.03
(32.42, 39.11 \$/cwt.)	1976	95.11	95.49	95.86	96.74	97.81	100.45	98.96
Feeder Steer Price	1971	94.51	93.84	94.31	95.66	98.31	108.13	93.34
(31.83, 36.93 \$/cwt.)	1976	94.61	94.50	95.07	96.04	97.45	101.65	101.04
Barrow-Gilt Price	1971	90.66	94.93	98.27	98.76	99.05	94.98	89.97
(18.57, 43.83 \$/cwt.)	1976	95.02	95.65	96.34	96.88	97.43	96.92	93.86

The increase realized for feed grain exports comes as result of lower domestic corn prices. Although there would likely be some increase due to a general price rise is the U. S. compared to importing countries (leading to a devalued dollar), this relation is not explicitly captured by the model. Total meat production is reduced as livestock prices received fall. The initial increases in non-fed beef production develops from declining placements on feed and an effort to reduce output through the slaughter of breeding stock.

Impacts of Increased Feed Grain Exports

Table VII lists estimated effects of an exogenous increase of five million tons in annual feed grain exports. This increase is comparable to a 20.2 percent increase in the level of exports for 1971 and a 9.6 percent increase in 1976. This simulation represents a viable policy alternative, since the government has the option of undertaking measures to induce increased grain exports. No immediate response is shown for feed grain output as production is hypothesized to be related to average price received in the past crop year. Corn price increases more substantially for the 1971 period in which the change reflects a large percentage change from the initial level of export activity. In general feed demand declines as livestock producers reduce output in response to increasing feed costs. The price of feeder steers falls rapidly as cattle feeders become less able to bid for livestock to be fattened. The price of feeder steers eventually recovers as reduced output allows the price of slaughter steers to increase, overriding the influence of reduced feeding margins. The reported increases in feed grain exports

TABLE VII

ESTIMATED IMPACTS OF A FIVE MILLION TON INCREASE IN ANNUAL FEED GRAIN EXPORTS

Endogenous Variable		Years 1	2	3	4	5	10	15
Corn Harvested Acres	1971	100.00	100.82	100.97	100.95	100.83	101.29	101.60
(64.1, 71.1 Mil. Acres)	1976	100.00	100.45	100.70	100.84	100.86	100.68	100.44
Feed Grain Harvested Acres	1971	100.00	100.21	100.24	100.28	100.24	100.38	100.51
(106.3, 106.8 Mil. Acres)	1976	100.00	100.08	100.15	100.16	100.16	100.13	100.08
Feed Grain Production	1971	100.00	100.49	100.57	100.59	100.50	100.80	101.02
(207.8, 212.3 Mil. Tons)	1976	100.00	100.25	100.41	100.48	100.49	100.39	100.25
Corn Price	1971	109.38	112.92	112.48	110.76	110.44	118.21	117.16
(1.27, 2.49 $/bu.)	1976	106.57	109.27	110.33	110.99	109.82	107.58	104.68
Feed Demand	1971	98.04	98.58	98.70	98.59	98.83	98.06	97.72
(143.4, 126.0 Mil. Tons)	1976	97.94	96.69	97.03	96.96	96.70	96.64	96.36
Feed Grain Exports	1971	120.15	119.59	118.84	118.64	118.55	118.93	120.39
(19.1, 57.0 Mil. Tons)	1976	109.57	115.04	114.84	114.80	114.91	114.58	113.92
Ending Feed Grain Stocks	1971	96.32	91.61	89.94	87.70	85.57	77.41	75.86
(50.4, 29.9 Mil. Tons)	1976	93.95	93.17	90.65	89.03	89.38	91.14	94.18
Fed Beef Production	1971	99.75	99.26	98.74	98.40	98.24	98.50	97.16
(17151, 16993 Mil. Lbs.)	1976	99.91	98.72	98.74	98.33	97.56	94.44	97.48
Non-Fed Beef Production	1971	102.03	104.67	104.91	102.30	99.89	102.40	104.29
(4547, 8673 Mil. Lbs.)	1976	100.91	104.40	104.41	104.54	105.23	99.35	99.85

TABLE VII (Continued)

Endogenous Variable		Years 1	2	3	4	5	10	15
Pork Production	1971	99.79	99.13	98.03	98.16	98.76	97.57	96.61
(14606, 12218 Mil. Lbs.)	1976	99.65	97.13	95.46	95.14	95.70	97.65	99.03
Slaughter Steer Price	1971	100.31	100.87	101.96	103.15	103.93	103.75	104.74
(32.42, 39.11 $/cwt.)	1976	100.05	101.69	101.58	101.80	102.16	103.60	102.13
Feeder Steer Price	1971	98.06	98.20	99.22	100.44	101.76	99.63	100.09
(31.33, 36.93 $/cwt.)	1976	97.99	97.37	97.57	97.80	98.36	101.99	101.26
Barrow -Gilt Price	1971	101.40	103.23	106.62	108.38	107.33	109.19	112.05
(18.57, 43.83 $/cwt.)	1976	100.47	105.88	107.89	108.39	107.14	106.06	103.14

are, of course, meaningless since exports were treated as an exogenous variable to provide estimated impacts.

Impacts of Exogenous Yield Increase for Corn

Table VIII displays the estimated responses of endogenous variables to an exogenous five percent increase in corn yields. This occurrence is a realistic possibility with a technological breakthrough. In general, feed grain output experiences growth, depressing market prices for feed grains. However, the increase in corn acreage is much lower than was anticipated. When the price of corn falls, both domestic and foreign use demands increase as feed grain stocks accumulate. The decline in corn price is not large enough to precipitate a decrease in acreage, with the exception of the long run impact in 1971. This is probably due to the estimated coefficients which weight corn support rate more heavily than market price. The cheaper input costs for meat production augments livestock output causing a decline in price. The largest decline is experienced in hog prices where the price of feed grains represents the largest proportion of variable costs.

Impacts of Increased Beef Imports

The estimated impacts of a 200 million pound increase in annual beef imports are shown in Table IX. Maximum beef imports allowed may be easily regulated by policy and is the principal government policy instrument directly affecting the livestock industry. An increase of this absolute magnitude is equivalent to a 12.2 percent increase in 1971 and 10.8 percent increase in 1976. The estimated impact of the feed grain markets is small, affecting corn price less than two percent

TABLE VIII

ESTIMATED IMPACTS OF A FIVE PERCENT INCREASE IN CORN YIELD PER ACRE

Endogenous Variable		Years 1	2	3	4	5	10	15
Corn Harvested Acres	1971	100.00	100.41	100.45	101.07	101.13	101.09	99.90
(64.1, 71.1 Mil. Acres)	1976	100.00	100.57	100.70	100.63	100.54	100.58	100.68
Feed Grain Harvested Acres	1971	100.00	100.16	100.41	100.50	100.55	100.57	100.20
(106.3, 106.8 Mil. Acres)	1976	100.00	100.22	100.53	100.65	100.61	100.62	100.67
Feed Grain Production	1971	103.87	104.18	104.33	104.65	104.73	104.72	103.93
(207.8, 212.3 Mil. Tons)	1976	104.09	104.49	104.72	104.77	104.71	104.75	104.81
Corn Price	1971	99.70	96.00	95.37	94.38	93.49	88.52	76.72
(1.27, 2.49 $/bu.)	1976	99.83	91.04	88.00	87.36	87.91	88.33	89.31
Feed Demand	1971	100.01	100.47	100.48	100.61	100.66	101.19	102.28
(143.4, 126.0 Mil. Tons)	1976	100.01	102.09	103.95	103.98	104.17	104.41	104.88
Feed Grain Exports	1971	100.15	101.78	101.77	102.07	102.41	104.87	112.57
(19.1, 57.0 Mil. Tons)	1976	100.08	106.53	109.07	109.48	109.28	108.77	107.25
Ending Feed Grain Stocks	1971	100.00	110.82	119.40	127.65	135.39	171.01	206.34
(50.4, 29.9 Mil. Tons)	1976	100.00	113.15	115.06	117.48	118.75	119.30	116.78
Fed Beef Production	1971	100.00	100.14	100.49	100.69	100.83	101.00	104.07
(17151, 16993 Mil. Lbs.)	1976	100.00	100.44	101.56	102.02	102.96	108.30	105.16
Non-Fed Beef Production	1971	100.00	99.71	98.54	99.08	99.49	98.21	95.64
(4547, 8673 Mil. Lbs.)	1976	100.00	98.85	94.38	93.43	92.79	98.65	97.58

TABLE VIII (Continued)

Endogenous Variable		Years 1	2	3	4	5	10	15
Pork Production	1971	100.00	100.08	100.62	101.00	100.94	101.84	104.47
(14606, 12218 Mil. Lbs.)	1976	100.00	100.72	103.42	104.85	105.58	104.66	103.77
Slaughter Steer Price	1971	100.00	99.74	99.18	98.56	98.08	97.40	93.04
(32.42, 39.11 $/cwt.)	1976	100.00	99.27	98.33	98.10	97.40	94.59	95.59
Feeder Steer Price	1971	100.00	100.38	100.15	99.76	99.45	100.26	98.35
(31.83, 36.93 $/cwt.)	1976	100.00	101.07	103.31	103.28	102.35	97.31	98.04
Barrow-Gilt Price	1971	100.00	99.34	97.60	95.64	95.22	93.00	83.37
(18.57, 43.83 $/cwt.)	1976	100.00	97.85	93.29	91.53	90.85	89.25	90.64

TABLE IX

ESTIMATED IMPACTS OF A 200 MILLION POUND INCREASE IN ANNUAL BEEF IMPORTS

Endogenous Variable		Years						
		1	2	3	4	5	10	15
Corn Harvested Acres	1971	100.00	99.99	99.98	99.99	100.00	99.94	99.87
(64.1, 71.1 Mil. Acres)	1976	100.00	100.00	99.99	99.98	99.98	99.98	99.96
Feed Grain Harvested Acres	1971	100.00	100.00	99.99	100.00	100.00	100.03	99.96
(106.3, 106.8 Mil. Acres)	1976	100.00	100.00	100.00	100.00	100.00	99.99	99.99
Feed Grain Production	1971	100.00	100.00	99.99	99.99	99.99	100.00	99.91
(207.8, 212.3 Mil. Tons)	1976	100.00	100.00	99.99	99.99	99.99	99.99	99.98
Corn Price	1971	99.85	99.82	99.91	99.81	99.90	99.09	98.51
(1.27, 2.49 $/bu.)	1976	99.96	99.80	99.76	99.76	99.81	99.71	99.44
Feed Demand	1971	99.92	99.81	99.80	99.84	99.84	99.80	99.78
(143.4, 126.0 Mil. Tons)	1976	99.93	99.99	99.95	99.95	99.96	99.92	99.87
Feed Grain Exports	1971	100.04	100.11	100.06	100.06	100.07	100.40	100.86
(19.1, 57.0 Mil. Tons)	1976	100.02	100.16	100.15	100.15	100.13	100.22	100.35
Ending Feed Grain Stocks	1971	100.03	100.48	100.74	100.95	101.13	102.11	102.89
(50.4, 29.9 Mil. Tons)	1976	100.05	100.08	100.11	100.14	100.12	100.19	100.34
Fed Beef Production	1971	99.98	99.76	99.70	99.56	99.40	99.32	99.99
(17151, 16993 Mil. Tons)	1976	99.99	99.97	99.95	99.89	99.81	99.59	99.85
Non-Fed Beef Production	1971	100.66	101.79	101.14	100.43	99.81	98.91	100.69
(4547, 8673 Mil. Tons)	1976	100.15	100.25	100.18	100.06	99.90	99.27	99.61

TABLE IX (Continued)

Endogenous Variable		Years 1	2	3	4	5	10	15
Pork Production	1971	100.00	99.73	99.57	99.65	99.76	100.14	99.92
(14606, 12218 Mil. Lbs.)	1976	99.98	99.98	99.97	99.93	99.91	100.07	100.13
Slaughter Steer Price	1971	98.68	98.87	99.05	99.29	99.63	99.90	98.56
(32.42, 39.11 $/cwt.)	1976	99.53	99.51	99.58	99.68	99.78	99.92	99.73
Feeder Steer Price	1971	98.76	98.56	98.71	98.98	99.38	100.39	98.62
(31.83, 36.93 $/cwt.)	1976	99.39	99.40	99.44	99.57	99.72	100.00	99.85
Barrow-Gilt Price	1971	98.40	99.21	99.87	99.84	99.81	99.01	98.55
(18.57, 43.83 $/cwt.)	1976	99.66	99.54	99.63	99.74	99.83	99.71	99.44

for all the periods simulated. All the livestock prices fall as the red meat supply expands. The price declines are not of great consequence, however, as total beef supply increases less than one percent. The price of barrows and gilts tends to recover at a rate faster than beef due to the shorter lag in supply response and the fact that beef and pork are imperfect substitutes.

To demonstrate the short run pattern and timing of adjustments in the livestock sectors, Table X displays the quarterly impact estimates for the simulations of increased beef imports. Because seasonal influences are strong, the adjustments being made are hard to visualize directly from the quarterly impact estimates. To remove the seasonality a four quarter moving average of the estimated impacts is given directly below the reported figures. The moving average is given by: $(M_t + M_{t-1} + M_{t-2} + M_{t-3}) \div 4.0$, where M_t represents the reported quarterly impact for t. This approach tends to smooth the seasonal variations in impacts and makes peaks and bottoms in the response patterns more identifiable.

The moving average of impacts for slaughter steer price demonstrates the maximum price response to be reached at approximately the same time for both periods. The magnitude of response is greater in 1971, but prices appear slower in recovery time for 1976. Meat production begins to respond to the new market setting in the second quarter with an increase in non-fed beef production. The effects of the change are similar for fed beef and pork production in 1971, but the time path of pork production is quite different for the simulation interval beginning in 1976. In 1976 pork production was increasing as hog prices were high. Increased domestic supplies of competing meats seems to have less impact when conditions are favorable for expansion in hog numbers.

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TABLE X

QUARTERLY IMPACTS OF A 200 MILLION POUND INCREASE IN ANNUAL BEEF IMPORTS

Endogenous Variable		Quarter 1	2	3	4	5	6	7	8	9	10	11	12
Fed Beef Production	1971	100.00	100.00	99.98	99.94	99.85	99.71	99.71	99.77	99.89	99.61	99.64	99.63
(4364, 4461 Mil. Lbs.)	M.A.	100.00	100.00	99.99	99.98	99.94	99.87	99.80	99.76	99.77	99.75	99.73	99.69
	1976	100.00	100.00	99.99	99.97	99.92	99.96	99.97	100.00	99.93	99.96	99.93	99.98
	M.A.	100.00	100.00	100.00	99.99	99.97	99.96	99.96	99.96	99.97	99.97	99.96	99.95
Non-Fed Beef Production	1971	100.00	100.24	100.61	101.60	102.02	101.32	101.57	102.24	101.36	101.00	100.87	101.31
(937, 2031 Mil. Lbs.)	M.A.	100.00	100.06	100.21	100.61	101.12	101.39	101.63	101.79	101.62	101.54	101.37	101.14
	1976	100.00	100.07	100.20	100.31	100.26	100.17	100.33	100.24	100.26	100.21	100.07	100.20
	M.A.	100.00	100.02	100.07	100.15	100.21	100.24	100.27	100.25	100.25	100.26	100.20	100.18
Total Beef Production	1971	100.00	100.05	100.14	100.36	100.25	100.01	100.10	100.26	100.13	99.86	99.89	99.98
(5301, 6492 Mil. Lbs.)	M.A.	100.00	100.01	100.05	100.14	100.20	100.19	100.18	100.16	100.13	100.09	100.04	99.97
	1976	100.00	100.03	100.09	100.10	100.03	100.04	100.08	100.08	100.02	100.02	99.98	100.06
	M.A.	100.00	100.01	100.03	100.05	100.06	100.07	100.06	100.06	100.06	100.05	100.03	100.02
Pork Production	1971	100.00	100.01	100.00	99.97	99.81	99.69	99.65	99.76	99.78	99.65	99.31	99.51
(3671, 2896 Mil. Lbs.)	M.A.	100.00	100.00	100.00	100.00	99.95	99.87	99.78	99.73	99.72	99.71	99.63	99.56
	1976	100.00	100.00	99.98	99.96	99.88	99.88	100.00	100.09	100.09	99.89	99.80	100.05
	M.A.	100.00	100.00	99.99	99.98	99.96	99.93	99.93	99.96	100.02	100.02	99.97	99.96
Slaughter Steer Price	1971	99.43	98.95	97.58	98.87	99.58	99.25	97.80	98.99	99.63	99.46	98.18	99.42
(26.94, 42.15 $/cwt.)	M.A.	99.86	99.60	98.99	98.71	98.75	98.82	98.88	98.91	98.92	98.97	99.07	99.17
	1976	99.62	99.10	99.26	100.17	99.68	98.98	99.22	100.19	99.65	99.10	99.38	100.20
	M.A.	99.91	99.68	99.50	99.54	99.55	99.52	99.51	99.52	99.51	99.54	99.58	99.58
Feeder Steer Price	1971	99.67	99.15	98.07	98.24	98.80	98.89	98.18	98.37	98.85	99.04	98.33	98.65
(30.84, 36.98 $/cwt.)	M.A.	99.92	99.71	99.22	98.78	98.57	98.50	98.53	98.56	98.57	98.61	98.65	98.72
	1976	99.72	99.23	99.00	99.59	99.60	99.36	99.16	99.50	99.59	99.29	99.23	99.67
	M.A.	99.93	99.74	99.49	99.39	99.36	99.39	99.43	99.41	99.40	99.39	99.40	99.45
Barrow-Gilt Price	1971	99.19	98.56	97.20	98.88	100.19	99.82	97.93	99.25	100.39	100.16	98.82	100.44
(17.60, 47.99 $/cwt.)	M.A.	99.80	99.44	98.74	98.46	98.70	99.02	99.21	99.30	99.35	99.43	99.66	99.95
	1976	99.68	99.25	99.48	100.22	99.86	99.18	99.14	100.12	99.50	99.22	99.65	100.28
	M.A.	99.92	99.73	99.60	99.66	99.70	99.69	99.60	99.58	99.49	99.50	99.62	99.66

Another noteworthly point is the response in total beef production to increased imports. For both simulations, the net effect is to increase beef output for at least the first two years following the change. For this period of time the increase in cows and non-fed steers and heifers slaughtered dominate the decrease in fed slaughter.

Other Impact Estimations

Additional impact analyses including increases in loan rate levels and changing the level of diversion payments under government programs are presented in the Appendix. Although these impact estimations have applicability in analyzing policy alternatives, they were felt to be tied more specifically to the time period of estimation than those presented in this chapter. For example, response to a change in the loan rate when the market price is relatively high would be expected to be small. The impact of any policy change affecting acreage and crop supply is likely to be highly dependent on existing market conditions. Also, policy instruments influencing crop supply are not often allowed to remain at fixed levels for more than a few years, so that intermediate and long run impacts of sustained changes carry little meaning.

The proposed changes analyzed in this chapter may be roughly extrapolated to other hypothesized situations to make the estimated impacts more general in application. For example, an increase of five million tons in feed grain exports causes an approximate increase in corn price to ten percent in 1971. Because corn price is the only influence by which the feed grain market situation is transmitted to the livestock markets, any set of circumstances causing a similar increase in corn price will have a similar effect on the livestock markets.

Because the model is nonlinear, caution should be exercised in applying the estimated impact to other levels of changes or changes in opposite directions for the same set of exogenous variables. In the few tests which were made to determine the sensitivity of impacts under alternative variable values, indications were that only rough approximations can be made by linearly extending the results presented.

Projections for 1978-1982

As an aid in forecasting for planning or policy purposes, the livestock-feed grain model may also be used to project endogenous variable values under assumed conditions. To demonstrate this use of the model, a five-year simulation was conducted for the 1978-1982 period. Assumed values for exogenous variables were based primarily on recent historical trends and government programs which have been announced.

Assumptions for Exogenous Variables

The level of inflation for the 1978-1982 model is assumed to average 6.8 percent per year. All the indices representing measures of general price movements are adjusted by this same factor. U. S. population is projected to grow by two million annually, reaching 225 million by 1982. Average per capita disposable income (nominal) is assumed to increase at an annual rate of 8.8 percent. The incomes in principal feed grain importing countries are projected to increase at an annual rate of 7.0 percent. These assumptions regarding the general economy and exogenous influences on demand for agricultural products appear reasonable considering recently observed trends.

Average annual imports of beef for the 1978-1982 projection period are assumed to be 1,830 million pounds. With an expected level of annual beef exports equal to 175 million pounds, net annual beef imports are projected at 1,655 million pounds. Net pork imports which are generally much lower than beef are assumed to average 133 million pounds annually. Both of these annual projections are seasonally adjusted for quarterly projections. Beef and pork by-product values which influence the wholesale to farm price margins were projected to increase by the same rate as the general rise in prices for 1978-1982. The value assumed for the pasture and range conditions index is 76.6, the average over the 1956-1976 period. The number of animal units in foreign countries which affects export demand for feed grains are projected to increase by slightly less than one percent annually. This figure is based on a linear trend extrapolation of growth in animal units since 1970 and appears to be a conservative estimate of the average growth possible.

The loan rates for major crops announced by the government for the 1978 crop year are as follows: corn, \$2.00; sorghum, \$1.90; barley, \$1.63; oats, \$1.03; wheat, \$2.25; soybeans, \$4.50; and cotton, 48.0¢. The loan rates are assumed to be constant through 1982 with the exception of the 1979 crop year for feed grains. Under the current law if the average farm price falls below 105 percent of the loan rate for the marketing year the loan rates may be adjusted downward by ten percent to improve the export prospects for U. S. grain. This option is assumed to be exercised for the 1979 crop year.

Target prices announced for 1978 are: corn, \$2.10; sorghum, \$2.28; barley, \$2.26; wheat, \$3.40; and cotton, 52.0¢. For years beyond 1978, target prices are assumed to increase in accordance with increased production costs. For 1978 additional diversion payments are offered for corn and sorghum. For corn \$.20 per bushel is offered for an additional ten percent acreage diversion. For grain sorghum the payment is \$.12 per bushel for a ten percent maximum increase in diverted acres. No additional diversion payments are expected after 1978. Requirements for minimum participation in the government programs calls for farmers to set aside ten percent of corn, sorghum, and barley acreage and 20 percent of wheat acreage.

Government programs for the 1978-1982 period are not entirely consistent with the programs over the period of estimation used for the crop acreage equations. This causes some problems in developing variable values for effective diversion and effective support rates. There are two sources of conflict between current government programs and those in past years. Diversion requirements for either direct payment or simple compliance with government programs is currently based on actual planted acreage. In past programs, diversion requirements were given as a percentage of base or allotment acreage. Also, support payments made in addition to loan rates are given by target price levels. These benefits are not known prior to planting as in previous programs, however, because the actual payments are calculated by the difference in the target price and the average price for five months following harvest. Only the maximum possible support payment, target price minus loan rate, is known with certainty.

For the 1978-1982 projections the differences caused by basing diversion requirements on planted rather than base acreage were presumed small enough to disregard, and, the percentages as stated in the programs were used directly as in previous years. For support payments, an alternative procedure was developed. Over the period 1961-1971, the price of feed grains remained low and close to the loan rate with large grain stocks on hand. For the two quarters following harvest during this period, corn price on the average was equal to 104 percent of the loan rate. Sorghum and barley prices averaged 107 and 113 percent of respective loan rates. These percentages were applied to the current level of loan rates to obtain the level of "expected" price for the five months following harvest. Expected support payments were then hypothesized as the difference in target price and the expected price. Although this approach may not be totally valid, it is suggested to be an improvement over simply using the difference in the target price and loan rate to measure the expected support payment.

Endogenous Variable Predictions

Table XI displays the projected values for annual variables. Harvested acreage of corn in 1979 is predicted to be at approximately the same level as 1978. This is the net result of simultaneously reducing the loan rate and the level of diversion payments. In 1980 the loan rate is increased to the 1978 level with no change in diversion payments with the resulting increase in harvested acres. The declines in acreage for 1981 and 1982 are the outcome of increased production costs with fixed support rates and higher target prices, inducing more farmers to comply with acreage restrictions.

Total production of feed grains relative to harvested acreage increases over the five-year period as yields increase. Feed grain stocks remain at a fairly stable level for the entire projection period.

TABLE XI

FIVE YEAR PROJECTIONS FOR ANNUAL ENDOGENOUS VARIABLES

Endogenous Variable	Year 1978	1979	1980	1981	1982
Corn Harvested Acres (Mil. Acres)	65.72	65.08	69.42	66.34	61.15
Sorghum Harvested Acres (Mil. Acres)	15.20	15.01	15.47	15.27	14.84
Barley Harvested Acres (Mil. Acres)	9.72	8.28	9.23	8.39	7.51
Oats Harvested Acres (Mil. Acres)	14.67	14.74	14.85	14.56	14.18
Feed Grain Harvested Acres (Mil. Acres)	105.31	103.10	108.97	104.57	97.68
Feed Grain Production (Mil. Tons)	218.11	212.18	233.31	225.99	211.95
Corn Price (Calendar Year) ($/bu.)	2.05	2.03	2.21	2.22	2.49
Feed Demand (Mil. Tons)	138.52	142.06	142.05	145.39	145.32
Feed Grain Exports (Mil. Tons)	58.85	54.93	58.96	62.98	63.81
Feed Grain Stocks (Oct. 1) (Mil. Tons)	56.69	60.34	54.80	61.65	57.10
Beef Cows (Jan. 1) (Thous. Head)	38747	37091	37128	38447	40644
Market Hogs (Dec. 1) (Thous. Head)	48822	57641	62928	66704	68253
Cow Slaughter (Thous. Head)	8572	6438	4914	4117	3811
Nonfed S. and H. Slaughter (Thous. Head)	2321	950	94	31	0
Fed S. and H. Slaughter (Thous. Head)	25861	24487	23134	22055	21843
Barrow and Gilt Slaughter (Thous. Head)	73569	78914	85700	90301	93093
Sow and Boar Slaughter (Thous. Head)	5431	5831	6301	6629	6858
Fed Beef Production (Mil. Lbs.)	17106	16436	15787	15236	15240
Nonfed Beef Production (Mil. Lbs.)	6099	4351	3066	2671	2614
Pork Production (Mil. Lbs.)	13519	14651	16001	16991	17679
Choice Steer Price ($/cwt.)	49.09	56.03	62.05	66.24	69.18
Feeder Steer Price ($/cwt.)	46.67	56.95	65.28	71.72	75.59
Barrow and Gilt Price ($/cwt.)	43.46	45.46	46.28	46.80	48.17

A gradual increase in exports occurs as foreign demand is predicted to continue increasing at a rate faster than foreign production.

For the livestock categories beef cows are not forecast to display an increase until January 1, 1980. Although this turning point may be correct, the rate of increase considering the price projections for cattle might be larger than that predicted. Market hogs are shown to be increasing throughout the five-year period. Apparently the strength in cattle prices is supporting the hog market to keep hog production profitable through 1982. This result could be true to a degree, but it seems doubtful that hog producers would not overproduce and need to reduce herd size at sometime during the period.

All types of cattle slaughter are declining through 1982 as producers hold animals to increase production inventories. Also, with a lower production base of brood cows fewer animals are available for head replacements, feeding or slaughter. The price projections for slaughter and feeder steers may be somewhat high, though not out of reason. If the response to higher prices in terms of brood cow numbers occurs more quickly than that in the simulation, the rise in prices would not be quite as dramatic.

Table XII provides quarterly projections of selected variables for 1978. The seasonal pattern shown and the projected levels for the first and second quarters may help those interested judge the acceptability of the results by making comparisons to data already published for 1978.

The forecast values presented in Tables XI and XII should only be considered an approximation of occurrences likely to happen subject to the assumed exogenous conditions. Unforeseen disruptions due to weather and policy changes can be so strong as to dominate the other

TABLE XII

QUARTERLY PROJECTIONS FOR ENDOGENOUS VARIABLES FOR 1978

Endogenous Variable	Quarter 1	2	3	4
Corn Price ($/bu.)	1.87	2.00	2.35	1.87
Feed Demand (Mil. Tons)	37.49	20.96	34.91	45.16
Feed Grain Exports (Mil. Tons)	15.04	12.74	17.37	13.72
Feed Grain Stocks (Mil. Tons)	129.59	91.71	56.70	188.81
Cow Slaughter (Thous. Head)	2053	1945	2225	2348
Nonfed S. and H. Slaughter (Thous. Head)	801	435	591	493
Fed S. and H. Slaughter (Thous. Head)	6707	6474	6761	5918
Barrow and Gilt Slaughter (Thous. Head)	18356	18242	18195	18776
Sow and Boar Slaughter (Thous. Head)	1091	1364	1422	1553
Fed Beef Production (Mil. Lbs.)	4517	4311	4356	3922
Nonfed Beef Production (Mil. Lbs.)	1520	1312	1648	1619
Pork Production (Mil. Lbs.)	3309	3353	3319	3539
Choice Steer Price ($/cwt.)	45.45	49.30	48.91	52.72
Feeder Steer Price ($/cwt.)	42.38	46.80	47.55	49.95
Barrow and Gilt Price ($/cwt.)	41.13	41.04	44.38	47.29

factors exogenous and endogenous to the economic subsector. In addition, errors in forecasting occur even when all assumptions are correct. This can be caused by measurement error and factors not included in the model because of assumed weak relationships with the subsector under study.

The problem of error compounding should also be recognized as highly possible when projecting endogenous variables for 20 quarters or five years. With an autoregressive error structure, as was the case in many of the equations estimated, a lagged dependent variable is implicitly included in each equation, which may add further to error buildup through successive simulation periods. Given this likelihood, the forecast values for the earlier years should be most reliable.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary of Research Effort

The decade of the 1970's has presented all subsectors of U. S. agriculture with a combination of problems never before encountered. Recognizing that recent experience may offer information to deal with similar problems in the future, the main objective of the study was to develop a model of the livestock-feed grain subsector capable of analyzing policy alternatives and providing outlook information. Principal subobjectives included analyzing specific policy alternatives, studying impacts of changing various factors considered exogenous to the subsector and providing a forecast of endogenous variables under an assumed scenario for 1978-1982.

Model development began with an outline of hypothesized relationships among variables within the livestock-feed grain economy. The proposed structure was demonstrated to be grounded in neoclassical microeconomic theory. Considering pragmatic issues, several violations of theoretical assumptions were noted, and various methods of handling the differences were proposed.

The principal tools used to quantify individual relationships were econometric techniques. A conscious effort was made to apply the correct statistical approach for each situation. Ordinary least squares and autoregressive least squares were used in cases which were hypothesized to contain explanatory variables independent of the disturbance term. In simultaneous blocks the technique of two-stage autoregressive least squares was applied. Relationships involved in the market hog sector were estimated with a method considered to be experimental for economics research. Combining the techniques of continuous delay modeling and optimal control theory, the submodel representing barrows and gilts on feed was treated as a production process requiring varying amounts of time for completion.

As a method of integrating the single and multiple relationships into a complete system, a simulation model of the livestock-feed grain economy was constructed. The model developed from this approach was demonstrated to be capable of simulating economic activity for feed grains and the three major livestock categories in the U. S. on a quarterly basis. The model was then subjected to several validity tests to determine its applicability to projection of endogenous variable values and policy analysis. Results obtained indicated accuracy levels in simulation appeared acceptable, and dynamic behavior over at least the intermediate run closely approximated reality.

The model was then employed to provide estimates of the impacts of explicit changes in exogenous variables and variations in policy measures. Observing the possibility that impacts may vary depending on initial conditions, each impact analysis was estimated from two starting points. The beginning years, 1971 and 1976, were selected on the basis of the contrasting economic settings. Impact estimates were then hypothesized to represent a range of possible outcomes for the values of endogenous variables in response to simulated changes. A second application of the model demonstrated its usefulness in projection of variables associated with the livestock-feed grain subsector.

In conclusion, several of the results from impact estimation are noteworthy. Personal income was found to carry substantial influence on the price of meat. An unexpected outcome from the simulation of increased income was the relative impact on the beef and pork sectors. Estimated relationships demonstrated pork rather than beef to be more strongly related to income when all factors endogenous to the meat sector were allowed to vary. In the simulation measuring the effects of increased prices in the general economy, feed grain harvested acres showed a tendency to increase in the short run. With increased costs there would likely be some switching to crops more productive per acre, but an absolute increase in acreage is unexpected.

Export markets for grain offer one of the most desirable alternatives for agricultural policy. If the government can induce increased grain exports, over-production becomes less of a problem, the cost of income support for producers could decline and the overall balance of trade could be improved. The costs involved in increasing exports and the depressing influence of higher grain prices on meat output are the undersirable aspects of any policy measure designed for higher export activity. The simulations of increased exports demonstrate the effect on feed grain price and resulting impact on meat output to be strongly related to relative stock levels.

The simulation measuring the impacts of an approximate ten percent increase in beef imports demonstrates annual prices of livestock to decline by less than two percent. One surprising result of the simulation is the short run increase in total beef production following increased beef imports. Thus, if the government views larger meat supplies as more desirable, allowing increased beef imports can aid in two ways, import supplies and domestic output. This, of course, assumes imports would increase if government permission was granted. In addition, the simulated impacts demonstrate such a policy might have less desirable long run effects.

Suggestions for Related Research

The research reported in this thesis could be considered a successful attempt in modeling a subsector of U. S. agriculture. Estimation results obtained are for the most part statistically appealing and the output from model application furnishes useful information on policy alternatives. In the course of completing the project, however, several discoveries were made which might aid other persons embarking on similar or related research work.

In the crop supply analysis portion of this research, heavy reliance was placed on the government policy variables, effective support rates and effective diversion payments. The approach taken to deflate supply response price variables is suggested to be an improvement over past modeling efforts in the area. However, the use of policy variables suitable for government programs in the 1960's and early 1970's creates problems in providing outlook information under current program specifications. Gross assumptions must be made to apply the effective support rate and effective diversion payment concepts to crop supply forecasts. The combined influence of various target prices and loan rates can, of course, be measured most accurately after several years of experience, but research worthy of consideration would be the development of a new set of policy variables consistent throughout current and past government programs.

Other recent changes in government programs create problems in applying the model reported herein to future policy analysis and projection work. Government stocks in the model were estimated as a behavioral relationship. This implicitly assumes the government has tended to function as a market participant in past years and the supply of grain held by the government has had a depressing influence on the price of grain. Although this specification ignores much of the structure involved in government operations, the estimation results tend to support the specification. The problem involved in the continued use of the estimated form is that current programs provide for a grain reserve completely isolated from the market within certain price bounds. Some of the grain will be held by the government directly while another portion will be held by producers who are paid storage to comply with program provisions. If total stock levels are predicted to rise appreciably in the future, some consideration should be made for the portion of stocks likely to be removed from the market.

The submodel of the market hog sector developed in this project is a technique which may be new to some economic researchers. In reporting its capabilities for simulating reality, it was treated much like the estimated econometric relationships. The characteristics of the complete model were described by the results, with the final output of prices and quantities derived from the combined influence of all relationships within the model. With results reported in this manner, the appealing attributes of individual relations or sets of relations become disguised by other elements in the model. Of course, for a model intended for use over varying lenths of run for a total economic subsector, the properties of the complete model are most important.

The form of modeling used for the market hog sector does appear to hold promise for improved methods of short term forecasting. The approach is intuitively appealing from the standpoint of its use of all available information on current inventories of market hogs. Most of these benefits in projecting barrow and gilt slaughter, however, tend to be exhausted after two quarters as projected values for pig crops completely replace the initial market hog inventories. The technique of combining continuous delay modeling and optimal control theory as a research method is more complex than the more familiar tool of regression and certain subjective judgments must be made in its use. However, the experience of this research suggest it may be superior in the ability to provide short run outlook information.

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APPENDIX

Table XIII shows the results of changing the effective diversion payment, the variable used to capture the influence of government payments offered for diverted acreage. For the 1971 crop year farmers were allowed to divert 20 percent of corn and grain sorghum base acreage for a payment of \$.32 per bushel of corn and \$.29 per bushel of grain sorghum on 50 percent of base acreage. These payment rates are equivalent to a payment of \$.80 per bushel of corn and \$.725 per bushel of grain sorghum on estimated production from diverted acreage ($.32 * .5 \div .20 = .80$). With 20 percent of the base qualifying for this payment level, the effective diversion payments are \$.16 and \$.145 for corn and sorghum, respectively.

The impact estimates given in Table XIII for 1971 demonstrate the effect of increasing the payments offered from 50 to 100 percent of base acreage for corn and sorghum. Under the assumed change in diverted acreage payments used to estimate impacts, barley was also included at a payment rate of \$.246 per bushel on 50 percent of base acreage. This increase in the barley diversion payment is comparable to relative payment levels for corn, sorghum and barley diverted acreage in past programs.

No diversion payments were offered in government feed grain programs for 1976, making effective diversion payments for all crops equal to zero. To simulate the changes comparable to those for 1971, effective diversion payments for corn, sorghum and barley were increased by

TABLE XIII

ESTIMATED IMPACTS OF INCREASING DIVERSION PAYMENTS

Endogenous Variable		Years 1	2	3	4	5	10	15
Corn Harvested Acres	1971	86.77	85.90	86.40	85.58	85.86	86.56	86.89
(64.1, 71.1 Mil. Acres)	1976	92.94	92.33	92.03	92.61	92.74	92.46	92.30
Feed Grain Harvested Acres	1971	88.55	87.82	87.88	87.09	87.07	87.19	87.36
(106.3, 106.8 Mil. Acres)	1976	93.62	93.17	92.91	93.23	93.30	93.25	93.20
Feed Grain Production	1971	91.91	91.47	92.26	91.85	92.09	92.76	93.07
(207.8, 212.3 Mil. Tons)	1976	96.58	96.31	96.29	97.08	97.26	97.21	97.10
Corn Price	1971	106.61	118.02	127.98	131.90	134.39	144.63	136.44
(1.27, 2.49 $/bu.)	1976	102.00	107.28	109.23	109.62	108.20	107.05	106.52
Feed Demand	1971	99.75	96.93	96.83	96.31	95.93	94.14	93.20
(143.4, 126.0 Mil. Tons)	1976	99.86	97.42	97.53	97.30	97.24	97.43	97.07
Feed Grain Exports	1971	95.94	91.11	87.53	86.10	85.24	79.23	77.76
(19.1, 57.0 Mil. Tons)	1976	98.99	94.72	93.05	92.82	93.76	94.80	95.69
Ending Feed Grain Stocks	1971	98.77	82.52	70.42	63.72	57.85	48.60	53.00
(50.4, 29.9 Mil. Tons)	1976	99.00	92.32	87.61	84.54	85.59	87.49	88.93
Fed Beef Production	1971	100.00	97.95	97.06	95.95	95.50	95.03	91.15
(17151, 16993 Mil. Lbs.)	1976	100.00	98.64	98.83	98.64	98.22	95.00	96.65
Non-Fed Beef Production	1971	100.00	105.53	106.88	107.50	106.28	108.16	103.02
(4547, 8673 Mil. Lbs.)	1976	100.00	102.18	103.16	104.79	105.70	100.31	100.68

TABLE XIII (Continued)

Endogenous Variable		Years 1	2	3	4	5	10	15
Pork Production	1971	100.00	97.95	96.08	94.05	93.92	91.45	91.79
(14606, 12218 Mil. Lbs.)	1976	100.00	97.33	96.07	95.69	96.21	97.38	98.03
Slaughter Steer Price	1971	100.00	103.41	105.24	108.03	109.91	112.49	115.36
(32.42, 39.11 $/cwt.)	1976	100.00	102.09	101.50	101.38	101.48	103.25	102.86
Feeder Steer Price	1971	99.92	98.49	99.56	100.23	101.12	98.17	105.97
(31.83, 36.93 $/cwt.)	1976	99.96	99.27	98.30	97.60	97.96	101.61	101.47
Barrow-Gilt Price	1971	99.99	110.05	115.52	124.83	127.47	131.56	132.14
(18.57, 43.83 $/cwt.)	1976	100.00	105.92	106.92	107.24	105.97	106.16	105.29

amounts equivalent to those assumed for 1971 (corn: \$.16; sorghum, \$.145; and barley: \$.123).

Total acreage diverted from feed grain production, an exogenous variable influencing yield per acre, was estimated to increase 16.8 million acres in 1971 and 11.7 million acres in 1976 due to the hypothesized changes in payments. These estimates were based on historical response to diversion programs and were used as input data for the simulation runs for 1971 and 1976.

The acreage of feed grains harvested is substantially reduced by increasing the level of diversion payment. The reduction is less in 1976 due to the increase in input costs experienced in the 1971 to 1976 interval. Feed grain production is also reduced but by a proportion less than that for acreage. The acreage removed from production is generally less productive and average yields tend to increase. Increasing feed grain prices reduces meat output, supporting a general rise in wholesale meat prices. The initial decline for feeder steer prices is accounted for by the reduced margins confronting cattle feeders. The change in corn price causes a greater response in the pork sector than in beef. This is a reflection of the relative importance of the price of feed grains on the two principal livestock sectors.

In Table XIV are given estimated impacts of reducing the proportion of allowable diverted acreage. The estimates are only given for 1971, since the initial conditions for 1976 provided for no direct payment on acres diverted. The simulated policy changes reduced payments to zero in 1971, offering no government induced incentive for removing land from production. The estimated policy impacts are generally the opposite direction and of the same order of magnitude as those presented in Table XIII for 1971.

TABLE XIV

ESTIMATED IMPACTS OF REDUCING DIVERSION PAYMENTS

Endogenous Variable	Year	Years 1	2	3	4	5	10	15
Corn Harvested Acres (64.1 Mil. Acres)	1971	113.23	113.70	113.62	114.66	114.82	115.04	113.71
F.G. Harvested Acres (106.3 Mil. Acres)	1971	110.34	110.60	110.45	110.71	110.79	110.90	110.49
F.G. Production (207.8 Mil. Tons)	1971	105.68	105.44	104.63	104.54	104.49	104.32	103.54
Corn Price (1.27 $/bu.)	1971	100.08	94.90	94.05	93.52	93.39	88.52	76.88
Feed Demand (143.4 Mil. Tons)	1971	99.97	100.56	100.62	100.71	110.69	101.19	102.26
F.G. Exports (19.1 Mil. Tons)	1971	100.01	102.21	102.26	102.39	102.46	104.85	112.51
Ending F.G. Stocks (50.4 Mil. Tons)	1971	99.15	115.77	126.72	135.05	142.01	173.08	203.82
Fed Beef Production (17151 Mil. Lbs.)	1971	100.00	100.16	100.62	100.87	100.97	100.93	104.09
Non-Fed Beef Production (4547 Mil. Lbs.)	1971	100.00	99.82	98.23	98.85	99.51	98.01	95.80
Pork Production (14606 Mil. Lbs.)	1971	100.00	100.08	100.77	101.31	101.12	101.88	104.44
Slaughter Steer Price (32.42 $/cwt.)	1971	100.00	99.69	98.96	98.18	97.73	97.60	93.00
Feeder Steer Price (31.83 $/cwt.)	1971	99.94	100.44	100.20	99.61	99.17	100.51	98.29
Barrow-Gilt Price (18.57 $/cwt.)	1971	100.00	99.27	96.99	94.37	94.33	93.05	83.43

In 1971 the price of corn was low relative to 1976 and fairly close to the loan rate. A policy simulation was made to analyze the impacts of increasing the loan rate offered by the government. To test the sensitivity of production and government stock levels, the loan rate was increased to a level five percent above the simulated annual market price for corn obtained in the base run. This value was equivalent to increasing the original $1.05 per bushel loan rate to $1.40, the same as a 33 percent increase. Because the government rarely increases the support rate of only one agricultural commodity the loan rates for competing crops (wheat, soybeans, other feed grains, and cotton) were increased by the same percentage. This policy change has a significant impact on stock accumulation, mostly in the form of government reserves. For this reason, the possibility that such a program would be implemented for an extensive period is unlikely. For the first ten years the price of corn remains at a level above the base simulated value. As stocks become extremely large, grain price is driven to lower levels by the fifteenth year of simulation. The initial higher grain prices produced the predictable results of reduced export demand and feed demand. Most output is also reduced in the face of increased input costs with resulting increased livestock prices.

TABLE XV

ESTIMATED IMPACTS OF INCREASING CORN LOAN RATE TO LEVEL FIVE PERCENT ABOVE CURRENT YEAR PRICE AND INCREASING COMPETING CROP LOAN RATES BY EQUIVALENT PERCENTAGES

Endogenous Variable	Year	Years 1	2	3	4	5	10	15
Corn Harvested Acres (64.1 Mil. Acres)	1971	101.08	102.44	104.44	105.28	105.38	105.31	104.00
F.G. Harvested Acres (106.3 Mil. Acres)	1971	102.63	104.27	104.98	105.77	106.07	106.44	106.00
F.G. Production (207.8 Mil. Tons)	1971	110.90	113.89	116.67	119.43	120.34	112.10	121.32
Corn Price (1.27 $/bu.)	1971	106.46	116.56	119.47	118.86	117.82	106.38	87.93
Feed Demand (143.4 Mil. Tons)	1971	99.24	96.27	96.89	97.29	97.06	97.56	98.87
F.G. Exports (19.1 Mil. Tons)	1971	95.52	90.72	90.30	90.83	91.45	96.25	105.82
Ending F.G. Stocks (50.4 Mil. Tons)	1971	103.73	148.97	189.84	238.13	285.68	527.88	880.79
Fed Beef Production (17151 Mil. Lbs.)	1971	99.89	97.80	97.15	96.78	96.73	98.96	101.61
Non-Fed Beef Production (4547 Mil. Lbs.)	1971	100.67	107.16	107.01	104.18	102.14	102.08	98.74
Pork Production (14606 Mil. Lbs.)	1971	99.91	97.79	96.05	95.03	95.99	97.82	101.39
Slaughter Steer Price (32.42 $/cwt.)	1971	100.17	103.63	105.06	106.56	107.41	102.72	97.33
Feeder Steer Price (31.83 $/cwt.)	1971	99.53	98.13	99.74	101.40	102.44	100.12	99.45
Barrow-Gilt Price (18.57 $/cwt.)	1971	100.68	111.18	115.31	120.17	118.74	107.90	94.57

VITA

Kendell Wayne Keith

Candidate for the Degree of

Doctor of Philosophy

Thesis: QUARTERLY SIMULATION MODEL OF THE UNITED STATES LIVESTOCK-FEED GRAIN ECONOMY

Major Field: Agricultural Economics

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