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CRADDOCK, William John, 1938-
THE EFFECT OF GRAIN PRICE ON THE PROFITABILITY OF LIVESTOCK PRODUCTION--AN ECONOMETRIC SIMULATION.

Iowa State University of Science and Technology, Ph.D., 1966
Economics, agricultural

University Microfilms, Inc., Ann Arbor, Michigan

THE EFFECT OF GRAIN PRICE ON THE PROFITABILITY OF LIVESTOCK PRODUCTION -- AN ECONOMETRIC SIMULATION

by

William John Craddock

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Agricultural Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State University
Of Science and Technology
Ames, Iowa

1966

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CHAPTER I. INTRODUCTION

Objectives

During the past several decades technological advancements have greatly expanded the United States capacity to produce feed grains. The demand for this output has not, however, expanded at a comparable rate. Government controlled farm programs have been used to offset the excess productive capacity. The result has been a generally higher level of prices for feed grains than would have otherwise existed.

Livestock producers have often objected to increases in the price of one of their major inputs. Other people such as Bottum (1) feel that these producers gain from abnormally high feed grain prices. Any information which could shed more light on this question would permit more effective farm policy decisions.

The objective of this study is to quantify the relationship between feed grain prices and the livestock sector of the farm industry to determine the direction and extent to which the livelihoods of livestock producers have been influenced by past feed grain policies. It is hypothesized that beyond the very short-run period[1] farmers, as livestock producers, have benefitted from farm programs which caused higher feed grain prices.

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[1]For cattle this period would be somewhat greater than 2 years, whereas for hogs it would be about 1 year. In broiler production any time over 3 months could be viewed as sufficiently long to allow the necessary changes in production.

In the short run producers would be expected to suffer an income loss. The sale of market type livestock would initially increase through animals being marketed at lower finished weights in response to the higher feed price. In addition, the sale of a higher than normal proportion of breeding stock during this contraction period would further depress livestock prices. Hence, the lower product price together with the higher feed cost would result in lower net returns per animal than would have otherwise been the case.

It is hypothesized that continuing higher grain prices would eventually result in a relative decrease in livestock production. Prices would correspondingly rise as the system approached the new equilibrium where fewer livestock were marketed. The hypothesis of this study is that the action and reaction to the input and output price signals would stabilize at a point where the larger gross revenue from product price increases would more than offset the increased feed costs, thereby giving a greater over-all profit.

One would not expect the producers of the several classes of livestock to share equally in the gains. The relative importance of grain as a feed input together with the elasticities and cross elasticities of demand would determine the relative shares. In this study it is hypothesized that farmers would receive a larger income gain from a hog enterprise than from cattle feeding. Since hogs consume a relatively larger proportion of their diet in the form of grain than cattle, their output would be expected to decline relatively more than for cattle. Hence, if both beef and pork had the same price elasticities of demand, the price of pork and hence hogs would increase relatively more than for beef. However, numerous studies[1] have found that the demand for pork is relatively more inelastic than beef. Thus even the same decrease in beef and pork production would be expected to give rise to a relatively larger increase in hog prices. The supposition of the previous hypothesis is that the increased price of hogs would be sufficient to generate a relatively greater increase in net returns than for cattle, even after considering the greater increase in feed costs for the former class of livestock.

Method of Analysis

The hypotheses were empirically tested by simulation analysis. A model of the national livestock-meat economy consisting of demand, supply and inventory equations was developed. Economic theory and deductive reasoning were used to isolate the relevant variables. Each equation relates one or more exogenous or explanatory variables to an endogenous or dependent variable. The model is complete in the sense of having all explanatory variables either estimated by other equations within the model, or given as data.

The objectives of the study indicated that the method used to estimate the structural coefficients of the econometric model should be capable of yielding positive rather than normative conclusions.

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[1] See for example Buchholz, et al. (5).

Regression analysis was deemed the most appropriate technique. While this method of estimation may be applied to either cross-sectional or time-series data, the desire to make inferences for a national market ruled out consideration of the former type of data.

Analyses of the livestock industry by Cromarty (12) and Egbert and Reutlinger (15) estimated structural coefficients from time-series data observed on an annual basis. Crom (8) recently completed an econometric model using semi-annual data. An observation period of either an annual or semi-annual duration obscures many short-run interactions in the livestock industry. The objectives and assumptions of this study led to the selection of the quarter year as the appropriate length of observation for most behavioral relationships. The only exceptions are the cattle inventory equations for which annual data are utilized.

A computer program was written which permitted the system of structural equations to function as a simulator model. The simulator estimates a unique set of values for all endogenous variables given the structural coefficients, a set of initial values for all variables and a set of data for the strictly exogenous variables.

The model was first verified by using historical exogenous data in the simulation runs and observing the accuracy in estimating the past values of the endogenous variables. It was found necessary to re-specify several equations to achieve the desired level of precision.

When the model operated satisfactorily over the historical period, those exogenous variables amenable to policy control were specified at hypothetical values. The simulator model generated a time sequence of dependent variables for each alternative set of exogenous variables. Through these controlled experimental conditions it was possible to estimate livestock production and prices associated with the assumed feed grain prices rather than the historical structure.

The influence of the hypothetical feed grain prices and the resulting simulated structure of endogenous variables on the livelihoods of livestock producers was determined on the basis of the change in per animal net returns from that estimated from the simulated economy based on actual exogenous conditions. The difference in per animal net returns was calculated for steer finishing, hog and broiler operations for each quarter in which the alternative exogenous conditions were assumed to exist.

CHAPTER II. THEORETICAL FRAMEWORK

The formulation of the empirical model to simulate the actions of the livestock economy was based on economic theory. The theory of consumer behavior and the theory of the firm were explicitly utilized; hence, the relevant theoretical framework underlying each will be outlined. Both theories start from individual decision units and are extended to consumer and producer behavior in aggregate.

Theory of Consumer Behavior

Static, normative consumption theory is premised on the rational consumer possessing full and complete knowledge, who, when faced with a given set of prices, seeks to maximize an abstract entity called utility, subject to certain budgetary restraints. It is not necessary to assume cardinally measurable utility. Rather it is sufficient that the marginal rates of substitution of one good for another be measurable (Hicks (44, p. 19)). This is possible under the assumption that the consumer possesses an ordinal utility measure. The ranking of commodities may be expressed mathematically by a utility function. The ordinal utility function for one consumer may be expressed as:

$$U = f(x_1, x_2, \ldots, x_n) \tag{2.1}$$

where x_i , $i = 1,\ldots,n$ are the quantities of commodities X_i , $i = 1,\ldots,n$ consumed. The budget restraint may be expressed as:

$$Y = \sum_{i=1}^{n} p_i x_i \tag{2.2}$$

where Y is total income available to the consumer and p_i , $i = 1,\ldots,n$ are the prices of products x_i. It is necessary that $f(x_1,\ldots,x_n)$ be continuous and possess continuous first- and second-order partial derivatives to derive the properties of demand functions by the differential calculus concept.

To find the conditions for utility maximization the technique of Lagrangean multipliers is utilized. The utility function, Equation 2.1, and the budget restraint, Equation 2.2, are combined to form the function:

$$U' = f(x_1,\ldots,x_n) + \lambda(Y - \sum_{i=1}^{n} p_i x_i) \tag{2.3}$$

where λ is the Lagrange multiplier. For those values of x_i which satisfy the budget restraint, U' is identically equal to U. To maximize U' (and hence U) Equation 2.3 is differentiated with respect to x_i and λ. This yields n + 1 unknowns in n + 1 equations.

The first-order condition for utility maximization is obtained by expressing the first n equations and unknowns as:

$$\frac{f_{i-v}}{f_{i-e}} = \frac{p_{i-v}}{p_{i-e}} \qquad i = 1,\ldots,n; \quad 0 \leq v \neq e \leq i \tag{2.4}$$

where f_i is the partial derivative of U with respect to commodity x_i. Hence, the marginal rate of substitution between any two goods must equal the ratio of their prices.

The second-order condition for a constrained maximum is that the bordered Hessian determinant derived by taking the second partial derivatives of U with respect to x_i and λ alternate in sign:

$$(-1)^n \cdot \begin{vmatrix} f_{11} & f_{12} & \cdots\cdots & f_{1n} & -p_1 \\ f_{21} & f_{22} & \cdots\cdots & f_{2n} & -p_2 \\ \vdots & & & & \vdots \\ f_{n1} & f_{n2} & \cdots\cdots & f_{nn} & -p_n \\ -p_1 & -p_2 & \cdots\cdots & -p_n & 0 \end{vmatrix} > 0 \qquad (2.5)$$

The expression f_{ij} $(i,j = 1,\ldots,n)$ is the second partial derivative, $\partial^2 U'/\partial x_i \partial x_j$ derived from Equation 2.3. In terms of indifference curve analysis this condition is equivalent to stating that indifference curves must be convex from below.

The consumer's demand curve for a particular commodity, which relates the quantity purchased as a function of product price, can be derived from utility maximization analysis. The n + 1 equations associated with the first-order conditions can be solved to yield the quantity of each commodity as a function of all prices and income:

$$x_i = f(p_1,\ldots,p_n,Y) \quad i = 1,\ldots,n \qquad (2.6)$$

The demand curve derived in this manner is a single-valued function of prices and income. This property follows from the second-order condition for utility maximization. The demand function is also homogeneous of the zeroth degree in prices and income. Hence, a proportionate change in all prices and income will not affect the quantity demanded of any good.

When demand curves are estimated for an entire population rather than for individual decision units, it is often the practice to place price rather than consumption in the "dependent" position (Fox (20, p. 47)). While for the individual consumer price may be exogenously given, this is generally not true for a population in total. Rather, for many commodities it is more likely that total production or consumption is predetermined and the market price adjusts accordingly.

Many simplified assumptions were imposed to derive the static normative demand function. For example, in reality consumers do not instantaneously adjust their consumption patterns to conform with changed market conditions. Often the perfect knowledge which is assumed in the static normative analysis is missing. In other cases inertia and the force of habit prevent consumers from capitalizing on a favorable situation.

While the demand function specified in Equation 2.6 is homogeneous of the zeroth degree in prices and income, these variables characteristically do not undergo proportionate changes. Hence, empirically estimated demand functions are often composed either of prices and income which have been deflated by a cost of living index or such a variable is explicitly included in the function.

As the general level of income increases, people's preference structure may change. Because incomes have generally improved in a systematic manner during the past several decades, it has often been the practice to measure this influence by the inclusion of a "trend" variable in the demand function.

Demand functions such as exemplified by Equation 2.6 which contain the prices of all commodities are not amenable to empirical estimation. It was first observed by Moore (65), however, that many of the hypothetical variables do not have practical significance. That is, the strength of the relationships between some variables is so small that they can effectively be ignored. In this way it is usually possible to reduce the number of variables in a given demand function to an operational level and still have a valid approximation to the theoretical ideal.

Theory of the Firm

Whereas the consuming unit sought to maximize utility subject to a budgeting restraint, the producing unit is assumed to maximize profit subject to its available resources and the given technology. The analysis initially relates to the firm operating in perfectly competitive product and factor markets. The model also assumes the absence of risk and uncertainty.

The production function mathematically expresses the relationship between the quantities of resource inputs and product outputs. Input and output levels are rates of flow per unit of time. Several lengths of "run" are distinguishable. The short-run production function is subject to three general restrictions:

1. Sufficiently short so that some resources are nonvariable.
2. Sufficiently short so that technological improvements do not alter the shape of the production function.

3. Sufficiently long to allow the completion of the necessary technical processes.

Longer run production functions are definable by the relaxation of condition (1).

A short-run production function for a single output can be represented by:

$$x = f(q_1, q_2, \ldots, q_m) \tag{2.7}$$

where x is the product output and q_i, $i = 1,\ldots,m$, are the quantities of the variable resource inputs.

The cost of production (C) is given by:

$$C = r_1q_1 + r_2q_2 + \ldots + r_mq_m + F \tag{2.8}$$

The cost of the variable inputs q_i are given by r_i, $i = 1,\ldots,m$. Fixed input costs are represented by F.

The profit (π) of the firm may be expressed as:

$$\pi = px - C \tag{2.9}$$

where p is the product price. Alternatively by substitution one may form the equation:

$$\pi = p \cdot f(q_1, \ldots, q_m) - \sum_{i=1}^{m} r_iq_i - F \tag{2.10}$$

If the production function is assumed to be a continuous single function with continuous first- and second-order partial derivatives, differential calculus may be used to demonstrate a number of features of production theory. In general, however, production functions need not fulfill this requirement, but may be a single point, discontinuous or a system of equations.

The first-order condition for profit maximization is determined from Equation 2.10 by setting the partial derivatives of profit with respect to q_i equal to zero. The resulting m equations may be expressed as:

$$p \cdot f_i = r_i \qquad i = 1,\ldots,m \tag{2.11}$$

where f_i, the marginal physical product (MPP) of resource i, is the partial derivative of π with respect to input i. The term $p \cdot f_i$ is the marginal value product (MVP) of the i-th input, or the rate at which the entrepreneur's profit increases with further applications of input Q_i. The first-order conditions for profit maximization require that each input be used to the point where the MVP equals input price. The optimal combination of inputs determined from the m equations of the form 2.14 specifies that for any two inputs, the ratio of the marginal physical products must equal the input price ratio.

$$f_i/f_j = r_i/r_j \qquad i,j = 1,\ldots,m \qquad i \neq j \tag{2.12}$$

As output is varied, relationship 2.12 describes the <u>expansion path</u> of the firm, or the optimal combinations of inputs for any given level of output. Formally, the expansion path is an implicit function of q_i.

$$g(q_1,\ldots,q_m) = 0 \tag{2.13}$$

The second-order condition for profit maximization requires that the principle minors of the relevant Hessian determinant alternate in sign:

$$\frac{\partial^2\pi}{\partial q_1^2} < 0; \quad \begin{vmatrix} \frac{\partial^2\pi}{\partial q_1^2} & \frac{\partial^2\pi}{\partial q_1\partial q_2} \\ \frac{\partial^2\pi}{\partial q_2\partial q_1} & \frac{\partial^2\pi}{\partial q_2^2} \end{vmatrix} > 0; \quad \begin{vmatrix} \frac{\partial^2\pi}{\partial q_1^2} & \frac{\partial^2\pi}{\partial q_1\partial q_2} & \frac{\partial^2\pi}{\partial q_1\partial q_3} \\ \frac{\partial^2\pi}{\partial q_2\partial q_1} & \frac{\partial^2\pi}{\partial q_2^2} & \frac{\partial^2\pi}{\partial q_2\partial q_3} \\ \frac{\partial^2\pi}{\partial q_3\partial q_1} & \frac{\partial^2\pi}{\partial q_3\partial q_2} & \frac{\partial^2\pi}{\partial q_3^2} \end{vmatrix} < 0;\ldots \tag{2.14}$$

When the successive determinants of 2.14 are expanded, it can be shown that profit must be decreasing with respect to further applications of any resource. Or alternatively, the marginal physical product of all inputs must be decreasing.

If the problem of the optimum combination of input resources is solved, one can proceed to estimate the static normative supply function for a particular product. A supply function represents the maximum output which a firm would supply at a given price; or conversely, the minimum price which is necessary to induce a firm to provide a given level of output. The supply function for the profit maximizing firm corresponds to that portion of the marginal cost function (MC) which is increasing and greater than the average variable cost of production.

The marginal cost function may be derived from Equations 2.7, 2.8 and 2.13. These three equations can be reduced to a single equation in which cost is stated as an explicit function of the level of output plus the cost of the fixed resources:

$$C = \phi(x) + F \tag{2.15}$$

The marginal cost function if determined by taking the partial derivative of total cost with respect to output:

$$MC = dC/dx = \phi'(x) \tag{2.16}$$

The profit maximizing equation 2.9 may now be expressed as:

$$\pi = px - \phi(x) - F \tag{2.17}$$

The profit maximizing level of output can be found by differentiating 2.17 with respect to output and setting the resulting equation equal to zero:

$$d\pi/dx = p - \phi'(x) = 0 \tag{2.18}$$

Hence, the optimum output corresponds to where marginal cost and product price are equal. It is thus dependent upon product and variable factor prices and the technological conditions expressed through the production function, but it is not influenced by the fixed factors.

A single firm frequently has the option of producing several different outputs. The profit maximizing output combinations will be specified using matrix notation. The first k elements of the vector consist of different plausible outputs, x_i ; i = 1,...,k. The remaining positions represent the negatives of the quantities of resources, q_i ; i = 1,...,h, necessary in the production of the k possible outputs.

$$\eta = \begin{bmatrix} x_1 \\ \vdots \\ x_k \\ -q_1 \\ \vdots \\ -q_h \end{bmatrix} \tag{2.19}$$

A vector ρ is established to specify the prices of the k outputs and h inputs. The price of the i-th product is represented as p_i ; $i = 1,\ldots,k$.

$$\rho = \begin{bmatrix} p_1 \\ \vdots \\ p_k \\ r_1 \\ \vdots \\ r_h \end{bmatrix} \tag{2.20}$$

The problem becomes one of maximizing $\rho'\eta$ subject to $f(\eta)$, the implicit production function, equal to some constant value. The principle of Lagrangean multipliers is utilized to form the equation:

$$L(\eta,\lambda) = \rho'\eta + \lambda f(\eta) \tag{2.21}$$

Taking the partial derivatives of $L(\eta,\lambda)$ and setting them equal to zero establishes the first-order profit maximizing condition:

$$\partial L/\partial\eta = \rho + \lambda\partial f/\partial\eta = 0 \tag{2.22}$$

$$\partial L/\partial\lambda = f(\eta) = 0 \tag{2.23}$$

The first-order condition will be specified in indicial notation. Equations of the form 2.22 can be arithmetically manipulated to yield:

$$-\frac{p_{i-v}}{p_{i-e}} = \frac{\partial y_{i-e}}{\partial y_{i-v}} \qquad i = 1,\ldots,k \; ; \; 0 \leq v \neq e \leq i \tag{2.24}$$

where $\partial y_{i-e}/\partial y_{i-v}$ is the partial derivative of the explicit function which specifies y_{i-e} as a function of y_{i-v} and inputs q_i. Hence, for any two products the ratio of their prices must equal their marginal rate of substitution for profit to be a maximum. The multi-product firm's static normative supply function for a particular product is now a function of the product and resource prices, but also the prices of products competitive in output.

$$x_i = f(p_1,\ldots,p_n,r_1,\ldots,r_m) \tag{2.25}$$

In practice producers do not immediately adjust to a new equilibrium in response to changes in the variables or parameters in the supply function. Imperfect knowledge, habit and inertia of the entrepreneur impede the adjustment process much the same as is true for consumer demand.[1] Many production processes use highly specialized, durable resources. Since these resources have a very low value outside of the enterprise, the entrepreneur may continue to produce even though he is not using the optimum combination of inputs, or perhaps not producing the optimum output combination, as is indicated when the depreciated value of the fixed resources is used in the optimization calculations.

In many industries once the production process is initiated, there is little opportunity to vary the resource or output combinations. This is particularly true of many forms of agricultural production. Once the crop is seeded, there is little that can be done to significantly vary the final output volume. Furthermore, many production processes are subject to considerable uncertainty. In agricultural crop production, once the production process has begun, the goal often becomes one of maximizing output subject to the available weather conditions.

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[1]The parallelism between the factors preventing the rapid realization of supply and demand equilibrium is especially clear when one recognizes that the producer can be considered a consumer of raw materials and the consumer as a supplier of labor resources.

The path of adjustment in response to changes in the underlying production conditions may follow the form of either Diagram A or B in Figure 2.1. The equilibrium position as specified by the optimiza-

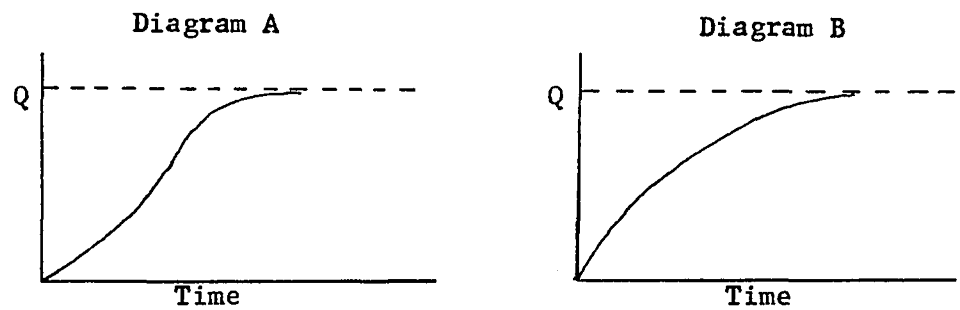

Figure 2.1. Time paths of adjustment

tion conditions is given by Q. In Figure 2.1, Diagram A, the rate of change increases as general market communication improves and as inflexibilities lessen, but eventually decreases as the adjustment approaches its limit Q.

Supply functions which circumscribe adjustment processes as indicated by Figure 2.1 may be approximated by distributed lag models. A simple supply equation where current output is a function of the current and past values of one resource is given by:

$$x_{1t} = b_1 r_{1t} + b_2 r_{1t-1} + b_3 r_{1t-2} + \dots + b_n r_{1t-n-1} \tag{2.26}$$

The variable x_{1t} is the output at time period t, while $r_{1t},\dots,r_{1t-n-1}$ are the prices of the resource q_1 at the corresponding time periods. Several problems arise in empirically estimating equations of the form 2.26. First if the lagged effect is sufficiently persistent, a large number of parameters must be estimated. Furthermore, if regression analysis is used as the estimation technique, it will be extremely difficult to obtain meaningful estimates of the coefficients because of the high intercorrelations between successively lagged variables.

Several theories have been developed to estimate distributed lag coefficients. Koyck's (53) specification is that the coefficients can be assumed to geometrically decline:

$$b_k = b\lambda^k \qquad k = 0, 1, \ldots ; \qquad 0 < \lambda < 1 \tag{2.27}$$

Relationship 2.26 may then be written as:

$$x_{1t} = br_{1t} + \lambda br_{1t-1} + \lambda^2 br_{1t-2} + \ldots \tag{2.28}$$

If 2.26 is lagged one period and multiplied through by λ and the resulting expression subtracted from 2.28, one obtains after rewriting:

$$x_{1t} = br_{1t} + \lambda x_{1t-1} \tag{2.29}$$

Under Koyck's specification the distributed lag relationship is reduced to one that involves only two variables and only two parameters to be estimated.

Nerlove (67) provides two alternative theories which directly justify the form of 2.29. The first is the "rigidity model." Suppose one assumes the structure where r_{1t} determines x^*_{1t}, the "desired value" of x_{1t}:

$$x^*_{1t} = \alpha r_{1t} \tag{2.30}$$

but that the adjustment to the desired value in one period is only gradual:

$$x_{1t} - x_{1t-1} = \delta(x^*_{1t} - x_{t-1}) \qquad 0 < \delta < 1 \tag{2.31}$$

where δ is the "coefficient of adjustment." If Equation 2.31 is substituted into 2.30, an equation of the form 2.32 results:

$$x_{1t} = \alpha\delta r_{1t} + (1 - \delta)x_{t-1} \tag{2.32}$$

Nerlove's second theory is the "expectation model." Suppose that the entrepreneur's anticipated value of r_{1t+1} is r^*_{1t} and it is this which determines x_{1t}:

$$x_{1t} = \alpha r^*_{1t} \tag{2.33}$$

It is further assumed that expectations are formed recursively as follows:

$$r^*_{1t} = r^*_{1t-1} + \delta(r_{1t} - r^*_{1t-1}) \qquad 0 < \delta < 1 \tag{2.34}$$

where δ is now the "coefficient of expectations." The expected value of r_{1t} is adjusted in proportion to the error made in predicting the value of the variable last period. If 2.34 is substituted into 2.33, Equation 2.32 is again obtained.

CHAPTER III. ECONOMETRIC CONSIDERATIONS

Introduction

Econometrics is concerned with measuring the presence and nature of the relationships among variables as suggested by economic theory. Four types of relationships are distinguishable in an economic system: (1) behavioral, (2) institutional, (3) technological and (4) identity equations. Behavioral relationships depict the aggregate outcomes of individual human behavior in decision making processes. Demand and supply functions are in this category. Institutional equations are the rules or laws of the institutions with which the econometric system is concerned. Technological functions express the relationship between two or more physical quantities. This information is essentially of an engineering character. The production function which expresses the relationship between beef as meat and the number of cattle slaughtered is a technological relationship. Identity equations are used for accounting purposes (i.e., summing disaggregates which can be treated as indistinguishable at another stage).

In a policy context, variables may be classified in the following manner. Target variables represent the objectives of economic policy. They are chosen because they are thought to be elements in the relevant welfare function. Often, however, the welfare function to be maximized is not known; hence, the target variables cannot be unequivocally defined. Instrument variables are the directly controlled variables or the means used by the policy maker to manipulate the system toward the desired outcomes. Variables endogenous to the system, but which do not explicitly enter into the welfare function being maximized, are designated as nonconditioned variables. Finally there remains the data variables which are determined outside the system of equations under study and are not in the control of the policy maker.

In the livestock-meat model it is assumed that policy is designed to influence the incomes of farmers. Feed grain prices are one group of instrument variables used to approximate this target. The amounts of agricultural inputs demanded may be thought of as nonconditioned variables. Agricultural service industries have a great interest in the values of these variables. However, in the formation of agricultural policy, it is assumed that the volume of business by the fertilizer and machinery industries is of so little concern that these variables may be safely ignored. Data variables include consumer income, population and the consumer price index. The very small cause-effect relationship from the feed-livestock system to these variables permits one to assume they are autonomously determined.

Regression Analysis

Alternative models

Regression analysis is one means to estimate the structural coefficients of the relationships in an economic system. In the classical least squares regression model the value of an observable random variable is expressed as a linear function of several observable non-stochastic variables and a nonobservable disturbance. In the most basic model, the error or disturbance term is assumed normally and independently distributed with an expectation of zero.

The general linear least squares regression model (L.S.) may be written in matrix notation as:

$$Y = XB + U \tag{3.1}$$

where:

Y is an nxl column vector of n observations on the endogenous or regressand variable;

X is an nxk matrix of exogenous or regressor variables;

B is a kxl column vector of parameters; and

U is an nxl column vector of error terms.

The least squares estimator for B is found by differentiating the matrix U'U with respect to B. Arithmetic manipulation yields the estimator:

$$\hat{B} = (X'X)^{-1}X'Y \tag{3.2}$$

The only restriction in deriving this estimator is that:

$$\text{rank } X = k < n \tag{3.3}$$

The estimator $\hat{B}$ is the "best," linear and unbiased estimator of B, if the following additional assumptions hold:

$$E(U) = 0 \tag{3.4}$$

$$E(UU') = \sigma^2 I_n \tag{3.5}$$

$$X \text{ is a set of fixed numbers} \tag{3.6}$$

The over-all variance of the regression, σ^2, is unbiasedly estimated by:

$$s^2 = U'U/n-k \tag{3.7}$$

The variance-covariance matrix for the regression coefficients is given by:

$$\mathrm{Var}(\hat{B}) = \sigma^2(X'X)^{-1} \tag{3.8}$$

and the sampling variance-covariance matrix by:

$$\widehat{\mathrm{Var}}(\hat{B}) = S^2(X'X)^{-1} \tag{3.9}$$

The L.S. regression model has been used extensively in empirical economic analyses. Its popularity is undoubtedly enhanced by the computational simplicity compared to alternative regression techniques. However, economic data generated under nonexperimental conditions usually violate one or more of the underlying assumptions of this model. For example, condition 3.5 requires that successive disturbances be generated independently of previous values. Time-series data which are widely used in economic regression studies are highly suspect of autocorrelated error terms. Ladd (54), working with time-series data to estimate behavioral equations and production functions, found from 26 to 66 percent (depending on the test used) of the equations had significantly autocorrelated errors. Klein (52, p. 314), Hurwicz (47) and Ladd (55) have found that there is an increased likelihood of autocorrelation in the errors as the unit of observation is shortened from a year, to a quarter, to a month.

Equation 3.5 may be rewritten in indicial notation as:

$$E(u_i u_j) = \sigma^2 \qquad i, j = 1,\ldots,n \qquad i = j \tag{3.10}$$

$$E(u_i u_j) = 0 \qquad i, j = 1,\ldots,n \qquad i \neq j \tag{3.11}$$

The Markoff Theorem (Tintner (79, p. 83)) indicates that only assumption 3.11 is necessary for $\hat{B}$ to remain the "best," linear and unbiased estimator in a unilaterally specified equation. Autocorrelation in the errors violates this assumption. Wold (107) has shown that the L.S. estimates are still unbiased. Fuller (25) demonstrates that this unbiased property is only true when no lagged regressand variables are included as regressors.

Autocorrelated errors cause L.S. estimates to be inconsistent. The sampling variance of the coefficient estimates, $\widehat{\mathrm{Var}(B)}$, may be excessively large compared to those obtainable by a different method of estimation. The estimates of these sampling variances, however, are likely to be seriously underestimated by the usual L.S. formula.

Where the model specification leads to the inclusion of one or more lagged regressand variables as regressors, Fuller (25) has shown that positive serial correlation in the errors may lead to a serious upward bias in the associated structural coefficient estimates. This, together with a downward biased sampling variance estimate, may lead to the invalid acceptance of the hypothesis that a lagged effect exists.

In economic relationships where a two-way cause-effect relationship exists between some variables, the system must be specified such that the number of equations equals the number of endogenous variables. Economic theory and the time lag of the observation unit will dictate that such a structure be composed of either simultaneous equations, a recursive set of equations or a recursive system with simultaneous subsets.

L.S. applied directly to an equation which is part of a simultaneous system violates assumption 3.6. The error term is no longer independent of the regressor variables. The L.S. estimates of the structural coefficients will be biased and inconsistent. However, if the equation is "just-identified," L.S. may be applied to the "reduced-form"[1] equation. Unbiased estimates will be found for the reduced-form coefficients. The estimates of the structural coefficients will be biased, though consistent.

All single equation simultaneous equation estimation techniques yield biased estimates of the structural parameters. Furthermore, the results are not invariant to the choice of dependent variable in any particular equation. However, these methods do yield consistent and asymptotically efficient estimates.

Systems methods of solving simultaneous equations yield consistent, asymptotically efficient and in general estimates which are invariant to the selection of dependent variable. However, estimation by systems methods is cumbersome, expensive and in most cases impossible because of insufficient observations.

A recursive system consists of a set of equations each containing a single endogenous variable other than those that have been estimated as dependent in prior equations. The endogenous variables enter the

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[1]The concept of identification and the derivation of reduced-form equations are explained in Johnston (49) and Goldberger (29).

system one at a time. The structure is built, link by link, from one period to the next and within each period in a specified order. If the disturbances are independent of the predetermined variables in an equation, L.S. will yield consistent and efficient, though biased, estimates. If the disturbances cannot be considered independent, then the estimated endogenous variable, rather than the actual values, must be used in succeeding equations of the chain. These estimates retain the consistency property, but are no longer efficient.

The livestock-meat model was specified as a recursive system with one simultaneous subset. Simultaneous equation techniques were not employed. While this form of estimator generates estimates which possess more desirable statistical properties than the ordinary least squares estimates, these superior attributes are large sample properties. In small samples, Monte Carlo studies[1] indicate that L.S. is often the appropriate estimation technique. The parameter estimates possess a smaller variance than those derived by simultaneous equation methods. Summers' (76) Monte Carlo study indicates that where errors in specification are involved, L.S. is the superior estimator. On these grounds the simultaneous subset of the livestock-meat model was estimated by single equation regression methods.

Preliminary L.S. results indicated that the error terms in most equations in the livestock-meat model were significantly autocorrelated. This problem was considered to be of sufficient importance

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[1]The results of several Monte Carlo studies are summarized in Johnston (49), Chapter 10.

to the successful operation of the model, to justify the spending of a considerable amount of time and money to estimate the equations by regression techniques which yielded independent error terms. For this reason an extensive discussion of the autocorrelation issue follows.

Autocorrelated errors

There are several reasons why the assumption of a serially independent error term may be invalid. One explanation is an incorrect specification of the form of the relationship between economic variables. For example, if a linear relationship is specified between Y and X when the true relationship is quadratic, then even though the disturbance term in the true relation may be nonautocorrelated, the quasi-disturbance term associated with the linear relation will contain a term in X^2. Hence, if there is any serial correlation in the X variables, then there will be serial correlation in the composite disturbance term. Since economic variables represented by time-series data are usually positively autocorrelated, the problem of incorrect functional form is a very plausible explanation of autocorrelation in the errors.

Autocorrelated disturbance terms may arise due to the omission of variables, both economic and noneconomic, from the analysis. Serial correlation in individual omitted variables need not necessarily imply a serially correlated disturbance term, for individual components may cancel one another out. However, if the serial correlation in the omitted variables is pervasive and if the omitted variables tend to move in phase, then there is a real possibility of an autocorrelated disturbance term. Important variables may be omitted either because they are not available in a quantifiable form or because their importance is not recognized. Because many time series are short, it may be necessary to neglect variables which individually have a small influence. However, collectively this influence might be quite significant. Variables such as age, sex, spatial distribution, changes in cultural patterns, technological development and many others have very high positive autocorrelations. Cochrane and Orcutt (6, p. 37) further point out that even where these autocorrelations within series are not high, their impact on the economic system is still likely to be autocorrelated.[1]

A third possible explanation of serially dependent disturbance terms is errors in the observations on the variables included in the analysis. The data used in a particular study have usually been gathered for a different purpose and may therefore not measure exactly what is required in the analysis under consideration. Cochrane and Orcutt (6, p. 38) state that if the discrepance is one of coverage, it seems reasonable to believe that the error terms involved will have much the same autoregressive properties as economic series

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[1]An example of this phenomenon is where rainfall may be a random series, yet the water level in the soil, being the result of rainfall over several years, could be positively autocorrelated.

in general. However, if the discrepance is what could truely be classified as pure error of observation, then randomness is much more likely. There is a strong likelihood, however, that an error of observation committed in one time period is likely to be repeated in the next time period and hence give rise to autocorrelated errors.

Even though a priori autocorrelated error terms are suspected, statistical verification is desirable before adopting the more complex and hence costlier techniques to circumvent the problem. A widely used statistic to test for autocorrelation is the von Neumann d statistic. If $\hat{u}_t$ $(t = 1,\ldots,n)$ are the residuals from a fitted least squares regression, then:

$$d = \frac{\sum_{t=2}^{n} (\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{n} \hat{u}_t^2} \qquad (3.12)$$

Durbin and Watson (14, pp. 173-175) have tabulated upper and lower bounds for d for different numbers of observations and explanatory variables. In conducting a one-sided test of positive autocorrelation, if the calculated value of d is less than d_L, then the hypothesis of random disturbances is rejected in favor of that of positive autocorrelation. If $d > d_U$, do not reject the hypothesis. If $d_L < d < d_U$, the test is inconclusive. A one-tailed test of negative autocorrelation is obtained by using $4 - d$ in the place of d in the above explanation.

While the d statistic is an easily calculated criterion, it nevertheless has several shortcomings. First as is true of any criterion which is based on residuals, it is only applicable where fixed regressors are used. When lagged values of the regressand are included as predetermined variables, it is not possible to consider all regressors fixed. The coefficients of the lagged variables "pick up" part of the autocorrelation in the residuals, at once biasing the estimated coefficients and invalidating the use of the Durbin-Watson test or any other statistic based on residuals. A further shortcoming of the d statistic when used in conjunction with the Durbin-Watson tables is the inconclusive range. This range is relatively large when the number of observations is about 25 or less and the number of explanatory variables is moderate. When the calculated d value falls in this range, there is a danger that the result is interpreted to mean that there is no need to reject the null-hypothesis of independence. Hence, there may be a bias towards overlooking too many cases of serial correlation.

Theil and Nagar (78) have tabulated another set of values for testing the null-hypothesis of residual independence for the d statistic. Basically this criterion defines as significant those values of d which are significant or inconclusive in the Durbin-Watson test. It has the limitations of the Durbin-Watson test in regard to use when the explanatory variables cannot be regarded as fixed. Since there is no inconclusive range, there is less danger of overlooking cases of autocorrelation.

The independence of successive disturbances may be tested by the ratio of the mean square successive difference to the variance:

$$k = \frac{\sum_{t=1}^{n-1} (\hat{u}_{t+1} - \hat{u}_t)^2}{n-1} \qquad \frac{\sum_{t=1}^{n} (\hat{u}_t - \hat{\bar{u}})^2}{n} \tag{3.13}$$

where $\hat{\bar{u}} = \sum_{t=1}^{n} \hat{u}_t / n$. If the successive differences are small (hence, k is small), there is some pattern such as a trend or cycle in the series and positive autocorrelation exists. If k is large, negative autocorrelation is present. The distribution of this ratio has been established by von Neumann (104) and by Hart and von Neumann (38). A table of significance levels has been calculated by Hart (37).

When lagged endogenous variables are included as regressors, one should proceed to estimate the structural coefficients as if autocorrelation is present. The problem, however, is that for several of the estimation techniques the autocorrelation coefficient must be known before such estimation can take place. The technique of autoregressive least squares (A.L.S.) simultaneously estimates the regression coefficients and the autocorrelation coefficient. A standard error is calculated for the autocorrelation coefficient to test its significance. If this coefficient is zero, then A.L.S. and L.S. yield the same estimates of the structural coefficients.

A frequent procedure is to assume the errors follow an autoregressive scheme. Suppose we have the equation:

$$Y_t = a + BX_t + u_t \tag{3.14}$$

and we postulate that u_t follows a first-order autoregressive scheme:

$$u_t = \rho u_{t-1} + \epsilon_t \qquad -1 < p < 1 \tag{3.15}$$

and ϵ_t satisfies the assumptions:

$$E(\epsilon_t) = 0 \tag{3.16}$$

$$E(\epsilon_t \epsilon_{t+j}) = \sigma_t^2 \qquad j = 0 \tag{3.17}$$

$$E(\epsilon_t \epsilon_{t+j}) = 0 \qquad j \neq 0 \tag{3.18}$$

Given these conditions it can be shown that:

$$E(u_t) = 0 \tag{3.19}$$

$$E(u_t u_{t-j}) = (1 + \rho^2 + \rho^4 + \ldots)\sigma_\epsilon^2 \qquad j = 0 \tag{3.20}$$

$$E(u_t u_{t-j}) = \sigma_u^2 = \sigma_\epsilon^2/(1 - \rho^2) \qquad j = 0 \tag{3.21}$$

$$E(u_t u_{t-j}) = \rho^j \sigma_u^2 \qquad j \neq 0 \tag{3.22}$$

Hence, when u_t follows a first-order autoregressive scheme, the assumption of a serially independent disturbance term is not fulfilled. Scheme 3.15 is the simplest possible type of autoregressive scheme. It can be shown that other more complex schemes also fail to fulfill the assumption of serial independence of the disturbance term.

For a general treatment of the problem we will revert to matrix notation where these matrices are defined as before, but where now instead of Equation 3.5 we have:

$$E(UU') = V \tag{3.23}$$

The variance-covariance matrix of the disturbance terms, V, is non-singular and of order nxn. If a first-order scheme is followed, then:

$$V = \sigma_u^2 \cdot \begin{bmatrix} 1 & \rho & \rho^2 & \cdots & \rho^{n-1} \\ \rho & 1 & \rho & \cdots & \rho^{n-2} \\ \rho^2 & & & & \\ \vdots & & & & \vdots \\ \rho^{n-2} & & & & \rho \\ \rho^{n-1} & \rho^{n-2} & \cdots & \rho & 1 \end{bmatrix} \tag{3.24}$$

The generalized least squares (G.L.S.) estimator of B is:

$$\hat{B}* = (X'V^{-1}X)^{-1}X'V^{-1}Y \tag{3.25}$$

rather than the L.S. estimator 3.2. The G.L.S. estimator 3.25 is the "best," linear and unbiased estimator. If the autocorrelation coefficients in V are known, G.L.S. can be used in a straightforward fashion.

If no a priori information is available for ρ, an iterative procedure may be used to estimate a value. L.S. is applied to the original variables to obtain residuals $\hat{u}_1, \hat{u}_2, \ldots, \hat{u}_n$. If the disturbance is assumed to follow the first-order scheme 3.15, then ρ can be estimated from the L.S. regression:

$$\hat{u}_t = r\hat{u}_{t-1} + e_t \tag{3.26}$$

The estimated coefficient r is used to transform the original variables. Least squares is applied to the transformed variables and the new residuals tested for autocorrelation. If the residuals are still significantly autocorrelated, a new ρ is estimated. This value is added to the preceding estimated ρ and the original variables again transformed. The procedure is continued until the estimated residuals are randomly distributed.

An approximation to the estimate of ρ derived above can be obtained directly from the von Neumann d statistic. The estimated ρ of Equation 3.26 is:

$$r = \frac{\sum_{t=2}^{n} (\hat{u}_t \hat{u}_{t-1})}{\sum_{t=2}^{n} \hat{u}_t^2} \tag{3.27}$$

The d statistic of Equation 3.12 can be expanded to read:

$$d = \frac{\sum_{t=2}^{n} (\hat{u}_t^2 - 2\hat{u}_t \hat{u}_{t-1} + \hat{u}_{t-1}^2)}{\sum_{t=1}^{n} \hat{u}_t^2} \tag{3.28}$$

If we allow the approximation:

$$\sum_{t=2}^{n} \hat{u}_t^2 \cong \sum_{t=1}^{n} \hat{u}_t^2 \cong \sum_{t=2}^{n} \hat{u}_{t-1}^2 \tag{3.29}$$

then:

$$d = \frac{2 \sum_{t=1}^{n} \hat{u}_t^2 - 2 \sum_{t=2}^{n} \hat{u}_t \hat{u}_{t-1}}{\sum_{t=1}^{n} \hat{u}_t^2} \tag{3.30}$$

$$d = 2 - 2r \quad \text{or} \quad r = 1 - d/2 \tag{3.31}$$

Autoregressive least squares is an iterative technique which reestimates the values of all parameters in the model, including those of the autoregressive structure until they converge to stable values. Suppose the equation to be estimated is of the form:

$$Y_t = a_0 + a_1 X_{1t} + a_2 X_{2t} + a_3 Y_{t-1} + u_t \tag{3.32}$$

where u_t follows the first-order autoregressive structure 3.15, ϵ_t satisfies assumptions 3.16, 3.17, 3.18 and:

$$E(X_{it}\epsilon_t) = 0 \quad \text{for all } i \qquad \text{for all } t \tag{3.33}$$

$$E(Y_{t-j}\epsilon_t) = 0 \quad j \geq 1 \tag{3.34}$$

Solving Equation 3.32 for u_t and lagging each variable one time period gives:

$$u_{t-1} = Y_{t-1} - a_0 - a_1X_{1t-1} - a_2X_{2t-1} - a_3Y_{t-2} \tag{3.35}$$

Substituting Equation 3.35 into 3.16 and then replacing u_t of Equation 3.32 by the resulting expression yields:

$$\begin{aligned} Y_t &= a_0 + a_1X_{1t} + a_2X_{2t} + (a_3 + \rho)Y_{t-1} - \rho a_0 - \rho a_1X_{1t-1} \\ &\quad - \rho a_2X_{2t-1} - \rho a_3Y_{t-2} + \epsilon_t \end{aligned} \tag{3.36}$$

Simplify by writing:

$$\begin{aligned} b_0 &= (1 - \rho)a_0 & b_4 &= -\rho a_1 \\ b_1 &= a_1 & b_5 &= -\rho a_2 \\ b_2 &= a_2 & b_6 &= -\rho a_3 \\ b_3 &= a_3 + \rho \end{aligned} \tag{3.37}$$

Equation 3.36 may then be rewritten as:

$$\begin{aligned} Y_t &= b_0 + b_1X_{1t} + b_2X_{2t} + b_3Y_{t-1} + b_4X_{1t-1} + b_5X_{2t-1} \\ &\quad + b_6Y_{t-2} + \epsilon_t \end{aligned} \tag{3.38}$$

If the autocorrelation coefficient, ρ, is equal to zero, Equation 3.38 reduces to Equation 3.32 and we obtain the ordinary least squares result. If ρ is equal to one, then the variables in Equation 3.38 may be arranged in the form of Equation 3.32 with the variables expressed as first differences. If $a_3 = \rho = 0$, then Y_{t-1} drops out of Equation 3.38 and the least squares regression of Y_t on X_{1t} and X_{2t} produces maximum likelihood estimates of a_0, a_1 and a_2. If $a_3 = 0$ and $\rho = 1$, then the L.S. regression of the first differences of the Y_t on the first differences of the X_{it} will again produce maximum likelihood estimates of a_0, a_1 and a_2.

When a_3 and ρ equal values different from those stated above, Equation 3.38 differs in two significant respects from the usual linear model. First two lagged values of the endogenous variable are used as explanatory variables. Secondly, three nonlinear restrictions are imposed on the coefficients, namely:

$$a_2 = b_2 = -b_5/\rho \tag{3.39}$$

$$a_3 = \left(b_3 \pm \sqrt{b_3^2 + 4b_6}\right)/2 \tag{3.40}$$

$$\rho = \left(b_3 \pm \sqrt{b_3^2 + 4b_6}\right)/2 \tag{3.41}$$

There is no guarantee that these nonlinear restrictions will be fulfilled if L.S. is applied directly to Equation 3.38. Seven parameters must be estimated while the original model contains only five.

To circumvent this problem an iterative technique has been developed by Fuller and Martin (27), (28) and Martin (61). Estimates of the five parameters of the model can be obtained which fulfill the nonlinear restrictions at a point where the residual sum of squares of Equation 3.38 is at least a local minimum.

The number of parameters to be estimated can be reduced from five to four by expressing all the variables in deviation form. The parameter, a_0, can be computed from the other four once their final solution is derived. A beginning set of estimates is selected for the remaining four parameters. The L.S. solution of Equation 3.38 utilizing Equation 3.37 affords a reasonable set of estimates. Let the beginning set of estimates be represented as:

$$P_0 = (\theta_{10}, \theta_{20}, \theta_{30}, \theta_{40}) \tag{3.42}$$

where:

$$\theta_{10} = a_1, \quad \theta_{20} = a_2, \quad \theta_{30} = a_3, \quad \theta_{40} = \rho$$

The second subscript on θ_i of Equation 3.42 refers to the iteration number. For example, θ_{10} refers to the start value of parameter a_1. Equation 3.38 is expanded about P_0 in a Taylor series discarding terms of higher than the first order. This yields:

$$Y_t = Y_{t0} + Z_{10}\Delta\theta_{10} + Z_{20}\Delta\theta_{20} + Z_{30}\Delta\theta_{30} + Z_{40}\Delta\theta_{40} \tag{3.43}$$

where:

$$\begin{aligned} Y_{t0} = {} & \theta_{10}X_{1t} + \theta_{20}X_{2t} + (\theta_{30} + \theta_{40})Y_{t-1} - \theta_{10}\theta_{40}X_{1t-1} \\ & - \theta_{20}\theta_{40}X_{2t-1} - \theta_{30}\theta_{40}Y_{t-2} \end{aligned} \tag{3.44}$$

$$Z_{10} = X_{1t} - \theta_{40}X_{1t-1} \tag{3.45}$$

$$Z_{20} = X_{2t} - \theta_{40}X_{2t-1} \tag{3.46}$$

$$Z_{30} = Y_{t-1} - \theta_{40}Y_{t-2} \tag{3.47}$$

$$Z_{40} = Y_{t-1} - \theta_{10}X_{1t-1} - \theta_{20}X_{2t-1} - \theta_{30}Y_{t-2} \tag{3.48}$$

The Z_{i0} are the first derivatives of Equation 3.38 with respect to each unknown parameter, and the $\Delta\theta_{i0}$ are the deviations of the θ_{i0} from the true parameters. The variable $Y_t - Y_{t0}$ is regressed on the Z_{i0} to obtain estimates of the $\Delta\theta_{i0}$.

If the estimated $\Delta\theta_{i0}$ are not small, then the process is repeated using as a second start point:

$$P_1 = (\theta_{10} + \Delta\hat{\theta}_{10}),\ (\theta_{20} + \Delta\hat{\theta}_{20}),\ (\theta_{30} + \Delta\hat{\theta}_{30}),\ (\theta_{40} + \Delta\hat{\theta}_{40}) \quad (3.49)$$

where the $\Delta\hat{\theta}_{i0}$ are the L.S. estimates of $\Delta\theta_{i0}$. In general each iteration will produce a smaller residual sum of squares than any previous iteration with the procedure thus converging to a final solution. This is not guaranteed, however. The $\Delta\hat{\theta}_i$ will be of the "correct sign" but may be so large as to actually increase the residual sum of squares. A dampening coefficient, h, can be used in subsequent start vectors such that $(P_i + h\Delta\hat{\theta}_i)$ is used, rather than $(P_i + \Delta\hat{\theta}_i)$. Since the changes were mentioned as being in the "right direction," it is guaranteed that $0 \leq h \leq 1$ such that the sum of squares associated with $(P_i + h\Delta\hat{\theta}_i)$ will be less than the sum of squares associated with (P_i). The sum of squares associated with $(P_i + h\Delta\hat{\theta}_i)$ will be designated as $Q(h)_{i+1}$.

One method for determining h, used by Fuller and Martin (28)[1], is to compute $Q(1)_{i+1}$. If this is less than $Q(0)_{i+1}$, the sum of squares at the start point, then use $(P_i + \Delta\hat{\theta}_i)$ as the next start.

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[1]Two further methods for determining h are suggested by Hartley (39).

If $Q(1)_{i+1}$ is greater than $Q(0)_{i+1}$, set $h = 1/2$ and compute $Q(1/2)_{i+1}$. If this is less than $Q(0)_{i-1}$, use $(P_i + 1/2\Delta\hat{\theta}_i)$ as the start vector for the next iteration; if not set $h = 1/4$, etc. In summary, the start vector for the next iteration is given by $(P_i + h\Delta\hat{\theta}_i)$ where h is the largest value in the geometric series 1, 1/2, 1/4,... such that $Q(h)_{i+1} < Q(0)_{i+1}$.

If the X_{it} are bounded and the ϵ_t normally distributed, the final set of estimates, P_j, are maximum likelihood estimates possessing the properties of consistency and asymptotic normality.

Autoregressive least squares only guarantee a local minimum of the residual sum of squares (local maximum of the likelihood function). If the several estimates of ρ computed from the initial L.S. estimation of Equation 3.38 are extremely divergent, there is a distinct possibility that multiple maxima of the likelihood function exist. A second initial start point should be selected and the iteration procedure repeated. If both initial start points converge to the same final solution, then there is reasonable certainty that a global maximum of the likelihood function was obtained. There is the possibility, however, that a third initial start vector would lead to a set of estimates with a lower residual sum of squares. If the first two initial start vectors lead to different final estimates and it is not desired to run a third estimation with a new start vector, the set of estimates with the smallest residual sum of squares may be used.

Only first-order autoregressive schemes have been explicitly considered. In order to obtain randomly distributed error terms, it may be necessary to consider higher order autoregressive schemes. For example, a second-order autoregressive scheme is:

$$u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + \epsilon_t \tag{3.50}$$

Assuming an error structure of this form will complicate the estimation schemes previously outlined but will not in general be unmanageable. If the A.L.S. technique is used, then both ρ_1 and ρ_2 are tested for significance. If ρ_2 is nonsignificant, then a first-order autoregressive scheme would be adopted.

In the foregone examination of the autocorrelation problem, the disturbance terms were assumed generated by a Markov process. Gurland (33) suggests that the assumption of stationarity essential to the Markov process is open to doubt when dealing with some time-series data. Much of the loss of efficiency in linear regression models which is attributed to the presence of autocorrelation may be due in great part to the evolutionary nature of the series.

If the Durbin-Watson test applied to L.S. residuals indicates that the errors of a particular equation are significantly autocorrelated, the specification of the equation should be examined more closely to determine whether there is something systematic which should have been incorporated. In general it is preferable to find the economic reasons behind the autocorrelation in the errors and incorporate them in the model, than to pursue complicated estimation schemes to circumvent the problem. Serial correlation can be eliminated by a particular technique, but there is no guarantee that it was generated by the assumed mechanism.

A computer program was written at Iowa State University in 1961 for the IBM 650 computer to solve the autoregressive least squares models. Recently Martin (62) revised the IBM 650 program to operate on the IBM 7094 computer. This latter program is capable of estimating the parameters of equations with up to two distributed lag coefficients, under the assumption that the errors follow either a first-order autoregressive scheme or are independently distributed. The IBM 7094 program written by Martin was made conformable to the IBM system/360-50 computer by the author.[1] This latter program was used to estimate the A.L.S. coefficients presented in this study.

Multicollinearity

Condition 3.3 of the least squares model indicates that no exact relationship may exist between any of the explanatory variables. If one explanatory variable is an exact linear function of another, then $|X'X| = 0$, and the inverse $(X'X)^{-1}$ used in the estimation of B does not exist.

When two explanatory variables are highly correlated, but not perfectly correlated, regression estimates are obtainable, but the reliability of these estimates is questionable. The determinant $|X'X|$ is likely to be small in the presence of highly interrelated variables. Division of the adjoint, X'X, by this small number will give a small inverse, $(X'X)^{-1}$. Haavelmo (34) argues that the estimate S^2 is not

[1]Interested parties may obtain a copy of the Fortran IV program from the author.

impaired by highly correlated independent variables. Hence, the standard errors of the regression coefficients, $\left(\widehat{\mathrm{Var}}(\hat{B})\right)^{1/2}$ are likely to be inflated. It will be difficult to reject very diverse hypotheses about the regression coefficients.

For any pair of independent variables, any degree of intercorrelation influences the respective estimates of the regression coefficients. It is impossible to estimate coefficients free from the influence of the correlated variables. Multicollinearity is one reason why structural coefficients estimated by regression analysis may be of a different magnitude, even of a different sign, than would be expected from economic theory.

Exact linear relationships between regressors are not common. However, it is not uncommon, particularly in time-series data, to find very high interrelations between these variables. Many economic variables are highly related to population growth, and thus in turn highly related to one another. Lagged variables are usually significantly correlated with one another and with the associated current variable. The formulation of the distributed lag models of Nerlove (67) and Koyck (53) presented in Chapter II were in part motivated by the problems of multicollinearity for models consisting of series of lagged variables.

Experience indicates that the multicollinearity problem is not severe if the correlation between any two variables is not greater than $|.7 \text{ to } .8|$. Where two variables are more highly correlated, a common practice is to remove one of the variables from the equation.

Economic theory will often indicate which variable may be removed. A noneconomic criterion is to remove the variable which has the lowest degree of correlation with the dependent variable.

Dummy variables

Economic relationships may be influenced by factors of a temporal character or which follow some regular, systematic pattern. These variables may furthermore be nonquantifiable. Dummy variables may be one means to include the influence of such factors in a regression equation.

Several distinct "regimes" may be observable in economic data. For example, time-series data may include several years when the economy was operating under wartime conditions. It may be hypothesized that several of the structural parameters of the economic relationship being estimated are correlated with this phenomenon. One means to handle the problem is to estimate a different regression equation for the data associated with each set of conditions. This procedure, however, does not allow the most efficient use of data in estimating those parameters which are not influenced by the abnormal conditions. On the other hand, it may be possible to use dummy variables in such a way as to isolate the several parameter estimates for those variables influenced by the wartime conditions, and yet pool the data for all time periods to obtain the most efficient estimates of the remaining coefficients.

The most common type of dummy variable is the zero-one formulation. This is appropriate when it is hypothesized that the intercept of the over-all equation is not the same for all observations. However, data and zeros may also be used to permit the slopes to vary under different circumstances.

In this study dummy variables are used extensively to allow either different intercepts or different slope coefficients according to the season of the year. For example, in a number of equations it is hypothesized that the intercept coefficient varies by quarter. The set of dummy variables most often used for this purpose is of the form:

Table 3.1 Dummy variable construct number one

Quarter	Variable X_1	X_2	X_3
4	1	0	0
3	0	1	0
2	0	0	1
1	0	0	0

This construct is repeated for each year for which data are used.

A regression is then run on the usual series of ones, the dummy variables and any other variables in the equation. It will be assumed that $\hat{B}_0$ is the estimate for the variable usually interpreted as the intercept, and $\hat{B}_1$, $\hat{B}_2$ and $\hat{B}_3$ are the respective estimates for variables

X_1, X_2 and X_3. In the fourth quarter the intercept term is now $\hat{B}_0 + \hat{B}_1$, in the third quarter $\hat{B}_0 + \hat{B}_2$, but in the first quarter it is $\hat{B}_0$.

The hypothesis that the intercept for the fourth quarter is different from that for the third quarter may be tested by the t value:

$$t = (\hat{B}_1 - \hat{B}_2)/S(a_{11} - 2a_{12} + a_{22})^{1/2} \tag{3.51}$$

where a_{ij} is the element corresponding to the i-th row and j-th column in the inverse matrix, $(X'X)^{-1}$.

It should be noted that innumerable different sets of dummy variables may be constructed to test the same hypotheses. The choice of a particular set can simplify the computations in hypothesis testing. For example, the following set of dummy variables could be constructed:

Table 3.2 Dummy variable construct number two

	Variable		
Quarter	X_1	X_2	X_3
4	1	0	0
3	0	0	0
2	0	1	0
1	0	0	1

The t value for the hypothesis tested above is now:

$$t = \hat{B}_1/S(a_{11})^{1/2} \tag{3.52}$$

which is the t value already calculated by the regression program for variable X_1.

If it is hypothesized that the slope coefficient for a particular variable varies by quarter, the actual data for the variable rather than ones are used in the construction of the set of dummy variables. Hypotheses are tested in much the same manner except for interpretation.

No attempt will be made to describe all the different sets of dummy variables used in this study. The particular variables used, together with the hypothesis under test, will be outlined when the empirical results are presented.

CHAPTER IV. ECONOMETRIC MODEL

Introduction

It is hypothesized that livestock producers receive a net income gain from governmental policy which creates higher than normal feed grain prices. The hypothesis is tested by means of an econometric model of the livestock industry.

Numerous behavioral relationships have been estimated for livestock products during the past 30 to 40 years.[1] Many of the studies have been concerned with the estimation of partial demand or supply functions rather than considering a comprehensive model of the several sectors of the livestock industry. In recent years more complex, highly interrelated models have been formulated. The increased availability of high-speed electronic computers has undoubtedly been a significant factor in this latter development.

Related Studies

The work of Cromarty (11), (12) in the late 1950's and early 1960's was one of the first attempts to formulate and empirically estimate a detailed, comprehensive model of the feed grain-livestock economy in the United States. Cromarty was concerned with predicting the impact of alternative Government programs on the wheat and

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[1]The multitude of these studies can be appreciated by examining Buchholz, et al. (5), which summarizes a sampling of several hundred such behavioral relationships which were published in the decade prior to 1962.

feed-livestock economies. Demand and supply equations were formulated for wheat, feed grains and broad categories of livestock products such as hogs, beef, dairy products, eggs and poultry meat. The structural parameters were estimated by regression analysis from annual time-series data over the period 1929-1957. Where the model formulation permitted, simultaneous equation regression techniques were employed.

The model was capable of predicting future prices and outputs for wheat, feed grains and livestock products given values for the exogenous variables. Several of the exogenous variables were open to Governmental policy control. Hence, it was possible to predict a set of prices and outputs corresponding to each alternative set of policy variables.

The model was not adaptable to economic simulation since there were a number of predetermined variables for which no predictive equations were formulated. Hence, since there was no test of the model's capability to interact for more than one period, only single period predictions could be validly made. For example, it was possible in 1959 to forecast the values of the endogenous variables for 1961 if a set of predetermined and strictly exogenous variables were assumed for 1961. However, it was not possible to predict 1961 values from a set of estimated predetermined variables. That is, the influence of a particular set of policy variables could only be examined for one period even though the full impact of the alternative policy assumption would undoubtedly take several years to work itself out.

In 1965 Egbert and Reutlinger (15) published preliminary results for an integrated supply-and-demand model of the livestock-feed sector. The model was designed for the specific purpose of making long-run projections. The commodities analyzed included cattle and calves, hogs, sheep and lambs, chickens, turkeys, eggs, milk and feed grains and other concentrates.

The model formulation was completely recursive. The structural parameters were estimated by regression analysis applied to annual time-series data for the period 1947 to 1963. The recursive nature of the model permitted the use of ordinary least squares regression. Since the structure of equations was "complete" in the sense that equations were formulated to estimate all predetermined variables at the current time period, economic simulation was possible. The model was verified by observing its correspondence to the historical time paths over the 1950-1963 period.

The Egbert-Reutlinger model did not estimate feed grain production. It was assumed that feed grain prices were determined by Governmental policy and were independent of livestock production. Expansion or contraction of livestock production operated with no causal effect on feed grain prices by assuming that the necessary increases or decreases in grain consumption were buffered by Governmental controlled surplus stocks. Corn prices were used as a proxy for all feed grain prices. Yearly projections of the prices and outputs of broad livestock classes were made to 1980 for different levels of corn prices.

Recently Crom (8) completed an evaluation of alternative market organizations in the livestock-meat economy by means of computer simulation. Cattle and hogs were the only two livestock classes analyzed. However, a more detailed consideration was given to each of these two sectors than done by the two previously mentioned studies. As well as demand and supply relationships, several inventory equations were explicitly introduced. Like the Egbert-Reutlinger model, the structure of equations was recursive. Time-series data were used as the basis for estimating the structural parameters. The unit of observation was the half-year for most equations. In these equations two distinct equations were formulated and parameters estimated for each behavioral relationship, one applying to each half of the calendar year. Several equations were estimated from data observed on an annual basis.

The assumed structure of the livestock-meat economy was verified by simulating the values of the endogenous variables over the mid-1955 to mid-1964 period. The failure of the initial parameter estimates as derived by ordinary least squares to adequately reproduce the historical time paths of the endogenous variables led to the introduction of many nonlinearities in the structural coefficients.

When the model operated with sufficient accuracy over the historical period, different historical values were assumed for those variables associated with market structure. It was thus possible to identify a set of endogenous variables which would have existed given the different market structure and given that the economic structure and parameter estimates would not have been different under the new conditions. No simulation runs were made assuming different historical feed grain prices although the model was adaptable to this use.

A set of estimates for the endogenous variables was made to 1975 for each of a number of different hypothesized market conditions. As in the Egbert-Reutlinger model, each predicted endogenous variable was conditional upon an initial set of conditions, previous estimates of endogenous variables as well as the projected estimates of the exogenous variables.

Analytical Framework

A major assumption of this study was that the levels of livestock output and prices do not directly influence feed grain prices or production. The prices of feed grains were assumed exogenously determined by an agency under Governmental control. Any difference between the feed requirements of livestock and feed production less nonlivestock utilization was assumed to be buffered by additions to, or subtractions from, Government controlled surpluses.

The livestock classes analyzed are: cattle, hogs and poultry. The cattle sector is confined to an analysis of the beef industry. The dairy industry was assumed independent of livestock and feed grain prices. Dairy cattle are thus treated as an exogenous component of total cattle slaughter. No attempt was made to analyze veal production. A large percentage of veal production is a by-product of the dairy industry and not particularly sensitive to feed or livestock prices.

The analysis of the poultry sector is restricted to the broiler industry. From 1953 to 1963 broiler consumption increased from 56 to 86 percent of total chicken consumption. The nonbroiler portion of chicken meat production is not analyzed in this study.

A seasonal demand exists for meat which is not associated with economic factors. For example, pork consumption is greater in the winter months than in the summer. Livestock production and marketing are also seasonally oriented. A greater proportion of the seasonal variation in a behavioral relationship can be isolated by selecting the quarterly observation to correspond to the seasons of the year, rather than the usual calendar subdivision. Dummy variables can then be used to remove this portion of the seasonal influence from the structural equation. The quarterly classification of months used in this study is:

First quarter: December, January, February

Second quarter: March, April, May

Third quarter: June, July, August

Fourth quarter: September, October, November

The historical period with which the hypothesis is concerned is from 1957 to 1964. It is also desired to project the livestock industry into the near future. In the selection of the historical period on which to base the structural coefficient estimates, it was thus necessary to have a period of time sufficiently long that at least one complete production cycle was included for each class of livestock when cycles existed.

Parameters of the cattle inventory equations were estimated from annual data covering the period 1953 to 1965. The remaining structural coefficients of the relationships associated with the cattle and hog industries were estimated from quarterly data from 1953 to 1964. Current data prior to 1953 were not used to estimate the coefficients of any equations. It was felt that the structural coefficients of the livestock industry were sufficiently different prior to 1953 because of the Korean Conflict and the post-World War II situation to exclude this period from the analysis.

The parameters of the equations relating to the poultry industry were estimated from quarterly data for the period 1956 to 1964. Data for a number of variables in the poultry relationships are not available prior to the third quarter of 1955.

While data for current variables were not used prior to 1953 for the cattle and hog relationships or 1956 for the poultry equations, the lagged nature of many variables meant that these observations were generated in an earlier current time period. For example, the cattle inventory equations are influenced by lagged price variables which originate as early as the third quarter of 1948.

The prices of the different feed grains are highly correlated. When two or more of these prices are used in a single equation, the high degree of multicollinearity leads to very unreliable parameter estimates. Rather than using a composite feed grain price index which would have an obscure interpretative meaning, corn prices are used as a proxy variable for all feed grain prices. The high correlation between corn and the other feed grain prices should result in a minimum of distortion to the economic model because of this procedure.

The spatial price variation problem is minimized by using prices for a base point rather than a composite weighted or unweighted average national price. Feeder calf prices are measured at the Kansas City market. All other price variables are Chicago based.

The data used in this study were obtained from secondary published sources. All quarterly price variables are a simple average of monthly data. In general, quarterly quantity variables were obtained by a summation of the relevant monthly data. The inventory variables are measured at a specific point in time.[1]

The data for several variables need special explanation. Monthly broiler production on a liveweight or ready-to-cook weight are not available prior to 1960. However, monthly hatchings of broiler type chicks are available from mid-1955 and yearly broiler production are available from 1950. Quarterly production of broilers were obtained by first aggregating monthly broiler chick hatchings into the quarterly classifications. In this aggregation hatchings were lagged 3 months through 1957, and thereafter they were lagged 2 months. These data estimate the number of broilers produced per quarter if no deaths or

[1]The values of the quarterly endogenous variables for 1953 through 1964 are included in Figure 5.1, while the corresponding data for 1965 and the first and second quarter of 1966 are given in Figure 5.24. The annual endogenous data for 1954 to 1964 and for 1965 and 1966 are given in Tables 5.1 and 5.2, respectively. The values of the exogenous variables for the period 1953 to mid-1966 are given in Table A.1 of the appendix.

other losses have occurred. To account for a possible difference between hatchings and numbers marketed and to obtain production data on a ready-to-cook basis, the following procedure was followed. Monthly lagged hatchings were aggregated into yearly data. Reported yearly ready-to-cook weight production was divided by the synthesized yearly lagged hatchings to give an average weight per bird. This average weight was then multiplied times the quarterly lagged hatchings pertaining to the particular year to give an estimated quarterly production. Implicit assumptions of this technique are that within years the lagged relationship between hatchings and marketability remains constant and that premarket losses due to death and other cuases do not vary by quarters.

Data on the commercial slaughter of cattle by biological and age classification are not available. However, Federally inspected slaughter of steers, heifers, cows and bulls are published. Data on the commercial slaughter of these first three classes of cattle were derived by assuming that each class was the same percentage of commercial slaughter as it was of Federally inspected slaughter. The same assumption and procedure were followed in estimating commercial slaughter of barrows and gilts and sows from Federally inspected slaughter data.

All price variables used in the model are nondeflated. The consumer price index for "all items" was used as an explicit variable in those relationships where price inflation is a relevant consideration.

Quarterly civilian resident population is the mid-quarter population as derived by a simple average of monthly data.

Personal disposable income is not published on a monthly basis. Hence, to obtain data which would correspond to the quarterly configuration of months used in this study, the following procedure was followed. Total personal income by months was aggregated into quarterly data. Personal tax and nontax payments were expressed as a percentage of total personal income by the customary calendar quarter year. It was assumed that the percentage of income which was taxed remained the same for the seasonal quarter year which has 2 months in common with the calendar quarter year. This percentage was subtracted from the total personal income aggregated from the monthly data to yield quarterly personal disposable income.

The food marketing wage rate variable used in this study was partially derived. In January 1961 the base used in the determination of these data was changed. Rather than using the data for each period as a separate variable, one variable was formed. Each series of quarterly data was fitted by ordinary least squares regression to a trend variable. The regression coefficients for the two trend variables were not significantly different from each other. Hence, the regression coefficients corresponding to the 1953-1960 data were used to project the regression line to the fourth quarter of 1964. The unexplained variation by quarters from the fitting of the 1961-1964 regression line was added to the projected values of the quarterly data for the same period. These composite observations together with the original 1953-1960 data are used as the food marketing wage rate variable.

To facilitate further discussion, the variables used in this study are listed in Figure 4.1. The "variable code name" refers to the computer language name. The code names are used extensively in further references to specific variables. An effort has been made to follow a mnemonic naming of variables whenever possible. A guide to the type of variable being measured is given by the second or third character of the coded name. A "P," "Q" or "S" in this position indicates respectively that either a "price," "quantity" or "stock or inventory" variable is associated with the code name. An "N" in any position in the coded variable name indicates that the variable is measured on a per capita basis.

The second column in Figure 4.1, when relevant, indicates the units in which the variables are measured. A brief description of each variable is also included. Unless otherwise specified in the "description," each variable is identified by quarter year.

Within the text the time unit of observation for a particular variable is designated by a subscript. Quarterly data are identified by the subscript t (t = 1 corresponds to the third quarter of 1950), annual data by the subscript y (y = 1 represents 1950).

VARIABLE CODE NAME	UNIT OF MEASURE	DESCRIPTION
BCN	LB.	COMMERCIAL CIVILIAN CONSUMPTION BEEF PER CAPITA.
BCN2	LB.	COMMERCIAL CIVILIAN CONSUMPTION BEEF PER CAPITA IN SECOND QUARTER, ZERO OTHERWISE.
BCN3	LB.	COMMERCIAL CIVILIAN CONSUMPTION BEEF PER CAPITA IN THIRD QUARTER, ZERO OTHERWISE.
BCN4	LB.	COMMERCIAL CIVILIAN CONSUMPTION BEEF PER CAPITA IN FOURTH QUARTER, ZERO OTHERWISE.
BMN	LB.	MILITARY CONSUMPTION COMMERCIAL BEEF PER CAPITA CIVILIAN POPULATION.
BPW	$	WHOLESALE STEER PRICE PER 100 LB. CHICAGO, LESS THAN CARLOT BASIS, 500-600 LB. CHOICE.
BQ	MIL. LB.	COMMERCIAL PRODUCTION BEEF.
BQN	LB.	COMMERCIAL PRODUCTION BEEF PER CAPITA.
BRCN	LB.	COMMERCIAL CIVILIAN CONSUMPTION BROILERS PER CAPITA.
BRF	$	PRICE PER LB. LIVEWEIGHT RECEIVED BY FARMERS FOR COMMERCIAL BROILERS.
BRGP	$	PRICE PER 100 LB. PAID BY FARMERS FOR BROILER GROWER MASH.
BRP	CENTS	PRICE PER LB. BROILERS, DELIVERED, GRADE A ICE PACKED CHICAGO.
BRQ	MIL. LB.	COMMERCIAL PRODUCTION BROILERS.
BRQN	LB.	COMMERCIAL PRODUCTION BROILERS PER CAPITA.
BRSN	LB.	COLD STORAGE HOLDINGS BROILERS PER CAPITA AT END OF QUARTER.

FIGURE 4.1 DESCRIPTION OF VARIABLES USED IN ECONOMETRIC MODEL OF LIVESTOCK-MEAT ECONOMY

VARIABLE CODE NAME	UNIT OF MEASURE	DESCRIPTION
BSN	LB.	COLD STORAGE HOLDINGS BEEF PER CAPITA AT END OF QUARTER.
BT	MIL. LB.	NET (IMPORTS MINUS EXPORTS) FOREIGN TRADE IN BEEF.
BTN	LB.	NET (IMPORTS MINUS EXPORTS) FOREIGN TRADE IN BEEF PER CAPITA.
CAAW	LB.	AVERAGE LIVEWEIGHT COMMERCIAL CATTLE SLAUGHTER.
CAQ	'000 HEAD	COMMERCIAL SLAUGHTER CATTLE.
CBQ	'000 HEAD	COMMERCIAL SLAUGHTER BEEF COWS.
CBS	'000 HEAD	BEEF COWS AND HEIFERS TWO YEARS AND OLDER, ON FARMS JANUARY 1.
CBS2	'000 HEAD	BEEF COWS AND HEIFERS TWO YEARS AND OLDER, ON FARMS JANUARY 1 IN SECOND QUARTER, ZERO OTHERWISE.
CBS3	'000 HEAD	BEEF COWS AND HEIFERS TWO YEARS AND OLDER, ON FARMS JANUARY 1 IN THIRD QUARTER, ZERO OTHERWISE.
CBS4	'000 HEAD	BEEF COWS AND HEIFERS TWO YEARS AND OLDER, ON FARMS JANUARY 1 IN FOURTH QUARTER, ZERO OTHERWISE.
CDS	'000 HEAD	DAIRY COWS ON FARMS JANUARY 1.
COQ	'000 HEAD	COMMERCIAL SLAUGHTER BEEF AND DAIRY COWS.
CP	$	PRICE PER BU. NO. 3 YELLOW CORN CHICAGO.
CPI	.....	CONSUMER PRICE INDEX, ALL ITEMS, 1957-59 = 100.

FIGURE 4.1 (CONTINUED)

VARIABLE CODE NAME	UNIT OF MEASURE	DESCRIPTION
CVS	'000 HEAD	BEEF CALVES ON FARMS JANUARY 1.
CVSA	'000 HEAD	BEEF CALVES ON FARMS JANUARY 1 IN SECOND, THIRD AND FOURTH QUARTERS BEEF CALVES ON FARMS JANUARY 1 OF PREVIOUS YEAR IN FIRST QUARTER.
CY	PERCENT	DRESSING YIELD, COMMERCIAL CATTLE SLAUGHTER.
D2	.....	ONE IN SECOND QUARTER, ZERO OTHERWISE.
D3	.....	ONE IN THIRD QUARTER, ZERO OTHERWISE.
D4	.....	ONE IN FOURTH QUARTER, ZERO OTHERWISE.
D55	.....	ONE IN ALL QUARTERS THROUGH 1955, ZERO OTHERWISE.
D56	.....	ONE IN ALL QUARTERS THROUGH 1956, ZERO OTHERWISE.
DHP	$	PRICE PER 100 LB. U.S. NO. 1,2 AND 3 GRADE 200-220 LB. BARROWS AND GILTS CHICAGO IN FIRST, SECOND, AND THIRD QUARTERS MINUS THREE TIMES HP IN FOURTH QUARTER.
DSFP34	$	SFP34 IN THIRD AND FOURTH QUARTERS WHEN SFP34 LESS THAN $24.00, ZERO OTHERWISE.
DSFQN	HEAD	SOWS FARROWING PER CAPITA THIRD AND FOURTH QUARTERS MINUS FIRST AND SECOND, ZERO IN SECOND AND THIRD QUARTERS.
FMW	$	WAGE PER HOUR FOOD MARKETING DISTRIBUTION EMPLOYEES.
G	PERCENT	RANGE-FEED CONDITION 17 WESTERN STATES.
HEQ	'000 HEAD	COMMERCIAL SLAUGHTER BEEF HEIFERS ONE TO TWO YEARS OLD.

FIGURE 4.1 (CONTINUED)

VARIABLE CODE NAME	UNIT OF MEASURE	DESCRIPTION
HES	'000 HEAD	BEEF HEIFERS ONE TO TWO YEARS OLD ON FARMS JANUARY 1.
HES2	'000 HEAD	BEEF HEIFERS ONE TO TWO YEARS OLD ON FARMS JANUARY 1 IN SECOND QUARTER, ZERO OTHERWISE.
HES3	'000 HEAD	BEEF HEIFERS ONE TO TWO YEARS OLD ON FARMS JANUARY 1 IN THIRD QUARTER, ZERO OTHERWISE.
HES4	'000 HEAD	BEEF HEIFERS ONE TO TWO YEARS OLD ON FARMS JANUARY 1 IN FOURTH QUARTER, ZERO OTHERWISE.
HESA	'000 HEAD	BEEF HEIFERS ONE TO TWO YEARS OLD ON FARMS JANUARY 1 IN SECOND, THIRD AND FOURTH QUARTERS BEEF HEIFERS ONE TO TWO YEARS OLD OF FARMS JANUARY 1 OF PREVIOUS YEAR IN FIRST QUARTER.
HP	$	PRICE PER 100 LB. U.S. NO. 1,2 AND 3 GRADE 200-220 LB. BARROWS AND GILTS CHICAGO.
HP2	$	PRICE PER 100 LB. U.S. NO. 1,2 AND 3 GRADE 200-220 LB. BARROWS AND GILTS CHICAGO IN SECOND QUARTER, ZERO OTHERWISE.
HQ	'000 HEAD	COMMERCIAL SLAUGHTER BARROWS AND GILTS.
P	'000	CIVILIAN RESIDENT POPULATION.
PCN	LB.	COMMERCIAL CIVILIAN CONSUMPTION PORK PER CAPITA.
PMN	LB.	MILITARY CONSUMPTION COMMERCIAL PORK PER CAPITA CIVILIAN POPULATION.
PPW	$	WHOLESALE PRICE PER 100 LB. PORK CUTS CHICAGO.

FIGURE 4.1 (CONTINUED)

VARIABLE CODE NAME	UNIT OF MEASURE	DESCRIPTION
PQ	MIL. LB.	COMMERCIAL PRODUCTION PORK.
PQN	LB.	COMMERCIAL PRODUCTION PORK PER CAPITA.
PSN	LB.	COLD STORAGE HOLDINGS PORK PER CAPITA AT END OF QUARTER
PTN	LB.	NET (IMPORTS MINUS EXPORTS) FOREIGN TRADE IN PORK PER CAPITA.
RCPI	.....	DEVIATIONS FROM REGRESSION WHEN CPI REGRESSED ON T.
RFMW	$	DEVIATIONS FROM REGRESSION WHEN FMW REGRESSED ON T.
RYN	$	DEVIATIONS FROM REGRESSION WHEN YN REGRESSED ON T.
SFP	$	PRICE PER 100 LB. GOOD AND CHOICE FEEDER CALVES KANSAS CITY.
SFP34	$	AVERAGE PRICE PER 100 LB. GOOD AND CHOICE FEEDER CALVES KANSAS CITY DURING THIRD AND FOURTH QUARTER, ZERO OTHERWISE.
SFQ	'000 HEAD	SOWS FARROWING.
SHQ	'000 HEAD	COMMERCIAL SLAUGHTER STEERS AND HEIFERS.
SHS	'000 HEAD	STEERS ONE YEAR AND OLDER AND HEIFERS ONE TO TWO YEARS OLD ON FARMS JANUARY 1.
SP	$	PRICE PER 100 LB. CHOICE SLAUGHTER STEERS CHICAGO.
SQ	'000 HEAD	COMMERCIAL SLAUGHTER SOWS.
STQ	'000 HEAD	COMMERCIAL SLAUGHTER STEERS.

FIGURE 4.1 (CONTINUED)

VARIABLE CODE NAME	UNIT OF MEASURE	DESCRIPTION
STS	'000 HEAD	STEERS ONE YEAR AND OLDER ON FARMS JANUARY 1.
STS2	'000 HEAD	STEERS ONE YEAR AND OLDER ON FARMS JANUARY 1 IN SECOND QUARTER, ZERO OTHERWISE.
STS3	'000 HEAD	STEERS ONE YEAR AND OLDER ON FARMS JANUARY 1 IN THIRD QUARTER, ZERO OTHERWISE.
STS4	'000 HEAD	STEERS ONE YEAR AND OLDER ON FARMS JANUARY 1 IN FOURTH QUARTER, ZERO OTHERWISE.
STSA	'000 HEAD	STEERS ONE YEAR AND OLDER ON FARMS JANUARY 1 IN SECOND, THIRD AND FOURTH QUARTERS STEERS ONE YEAR AND OLDER ON FARMS JANUARY 1 OF PREVIOUS YEAR IN FIRST QUARTER.
T	.....	TREND 1 IN FIRST QUARTER 1953, 2 IN SECOND QUARTER 1953, ... , 48 IN FOURTH QUARTER 1964, ... , 68 IN FOURTH QUARTER 1969.
T24	.....	ZERO IN FIRST AND THIRD QUARTERS, MINUS TREND IN FOURTH QUARTER, TREND IN SECOND QUARTER.
TA12	.....	ZERO IN THIRD AND FOURTH QUARTERS, ONE IN FIRST AND SECOND QUARTERS 1953, TWO IN FIRST AND SECOND QUARTERS 1954, ... , 17 IN FIRST AND SECOND QUARTERS 1969.
TB40	.....	ONE IN FIRST, SECOND AND THIRD QUARTERS, MINUS THREE IN FOURTH QUARTER.
YN	$	PERSONAL DISPOSABLE INCOME PER CAPITA.
ZAQ	'000 HEAD	COMMERCIAL SLAUGHTER HOGS.
ZAW	LB.	AVERAGE LIVEWEIGHT PER HEAD COMMERCIAL HOG SLAUGHTER.

FIGURE 4.1 (CONTINUED)

Model Formulation

Causal ordering

The objectives of this study dictate that a relatively short unit of observation is the most appropriate. Where possible the model formulation is in terms of the quarter year. Under such a time dimension current livestock production is not significantly influenced by current livestock or feed prices. Major production decisions must be formulated and implemented several quarters or even several years before the associated output is realized. While production decisions are in part based on anticipated future prices, uncertainty causes these expectations to be strongly influenced by current and past price experiences.

The perishable nature of meat, on the other hand, establishes supply offered as the major determinant of short-run price. Retail, wholesale and live animal prices are highly interrelated. However, price is basically formulated at the wholesale marketing level with the other prices then being aligned to it. At any one stage of price making there is a strong interdependence between the prices of the several classes of meat. These prices are simultaneously determined.

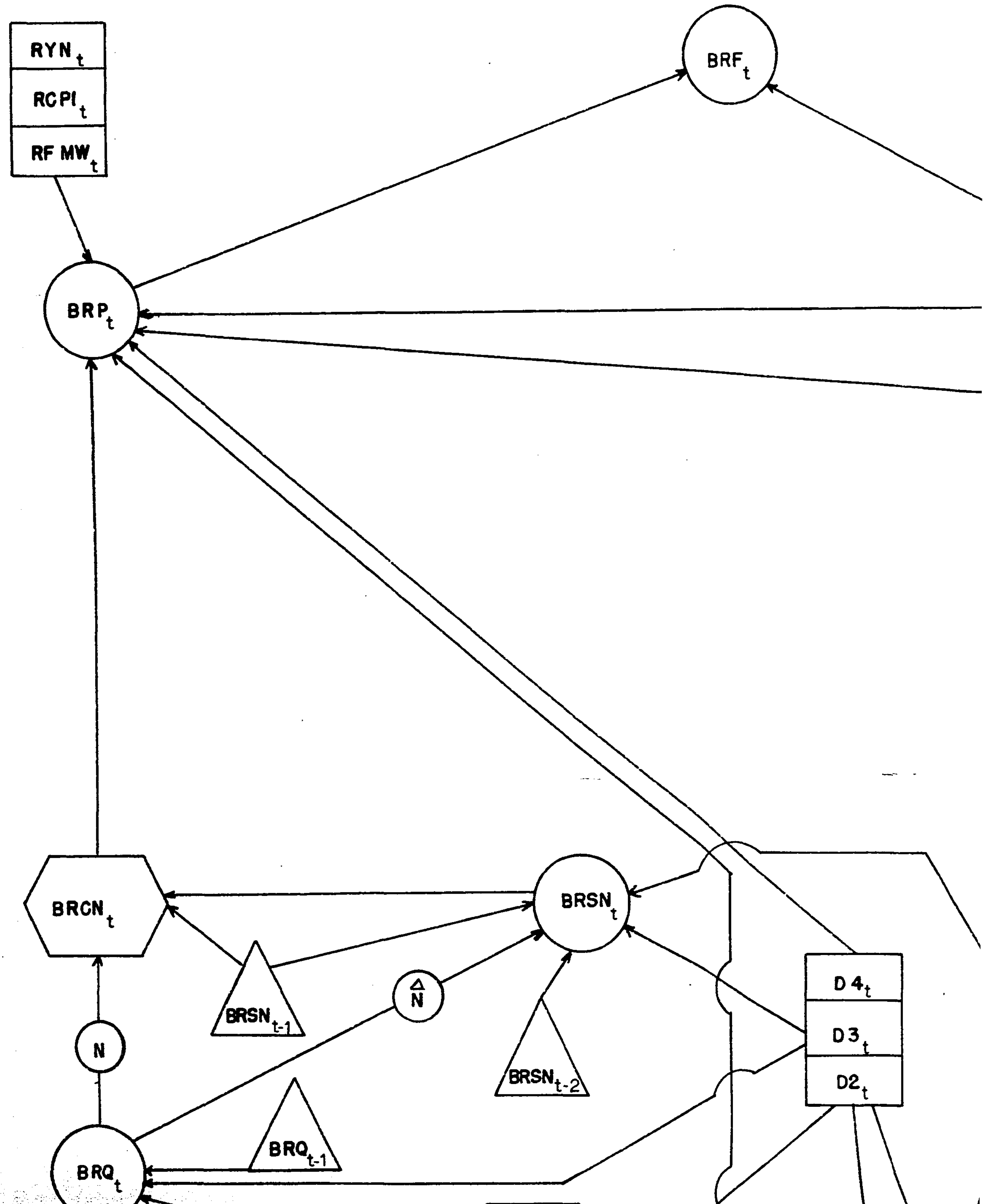
The causal relationships within the livestock-meat economy permit a sequential ordering of the structural equations. The relationships which are independently formulated, together with the simultaneous subsets, are intermixed with the recursive structure in a manner which retains the sequential ordering.

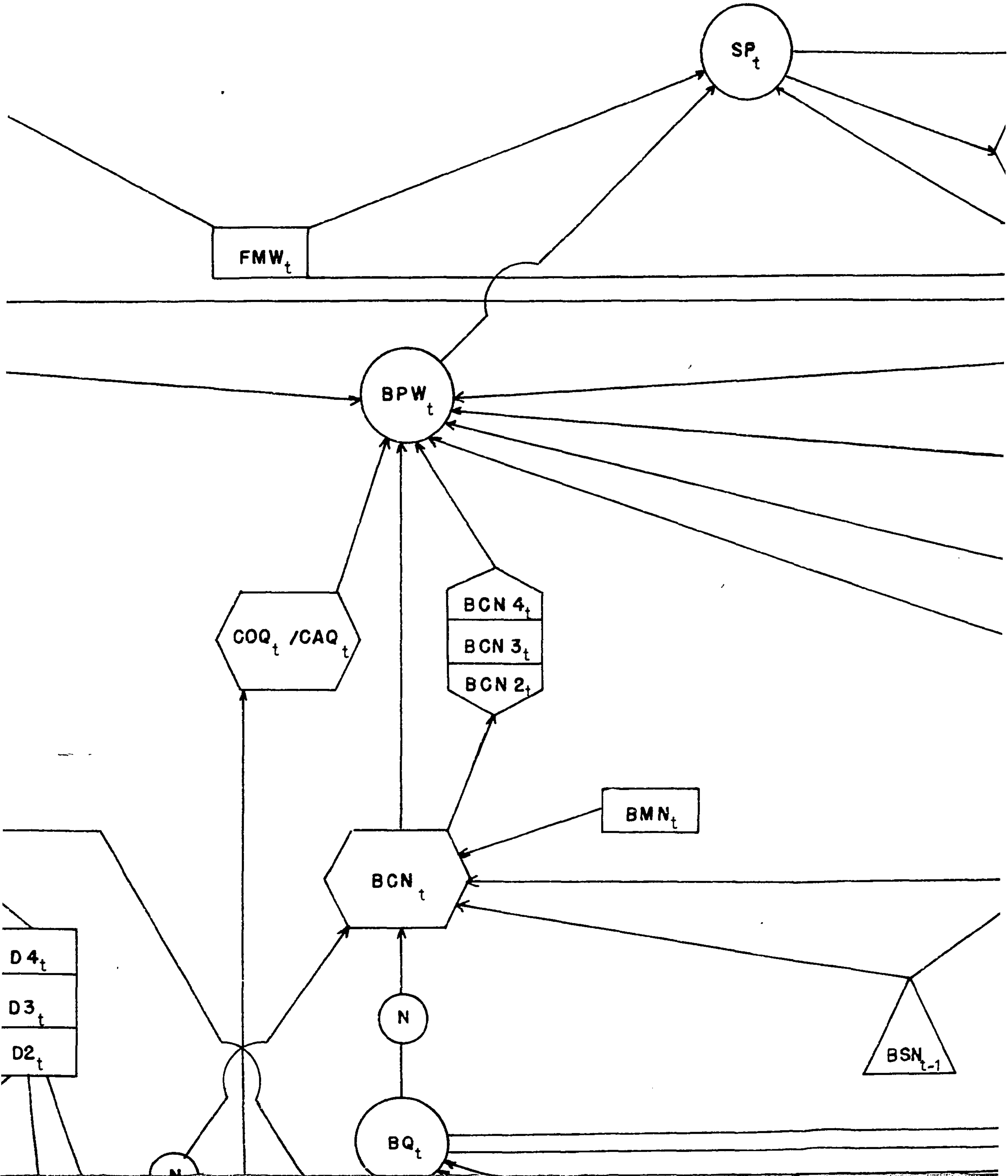
A schematic representation of the livestock-meat economy is given in Figure 4.2. Current endogenous variables appear as circles. Strictly exogenous variables are represented by rectangles. Endogenous variables predetermined in other than the current period are designated by diamond shaped symbols. Identity relationships are indicated through hexagonal boxes. The paths of major influence relevant to statistical estimation are shown by lines with arrows at their heads. Variables which are simultaneously determined are joined by a line with an arrow at each end. Lines which are intersected by a circle containing an "N," "Δ" or "Δ^2" indicate that the causal variable is either transformed to a per capita basis or expressed as its first or second difference before entering the effected relationship.

The coded names appearing in Figure 4.2 are defined and explained in Figure 4.1. Two further symbolic notations not described there are Δ and Δ^2. A variable code name preceded by one of these symbols indicates that the variable is measured as either its first or second difference (i.e., $\Delta HP_{t-2} = HP_{t-2} - HP_{t-3}$; $\Delta^2 HP_{t-2} = \Delta HP_{t-2} - \Delta HP_{t-3}$).

As an example of the sequential ordering of the relationships in the livestock-meat economy, the structure of the pork sector will be outlined. One may break into the system of equations at any point. This description will start from the most basic decision formulating stage.

The decision to farrow sows is made approximately two quarters before farrowing takes place. The anticipated price of market hogs about four quarters hence and the expected price of feed inputs during the production period are important considerations relevant to this decision. This model assumes that the price expectations can be


RYN t
RCPI t
RF MW t
BRF t
BRP t
BRCN t
BRSN t
BRSN t-1
BRSN t-2
N
N
BRQ t-1
BRQ t
D 4 t
D 3 t
D 2 t



SP_t
FMW_t
BPW_t
COQ_t / CAQ_t
$BCN4_t$
$BCN3_t$
$BCN2_t$
BMN_t
BCN_t
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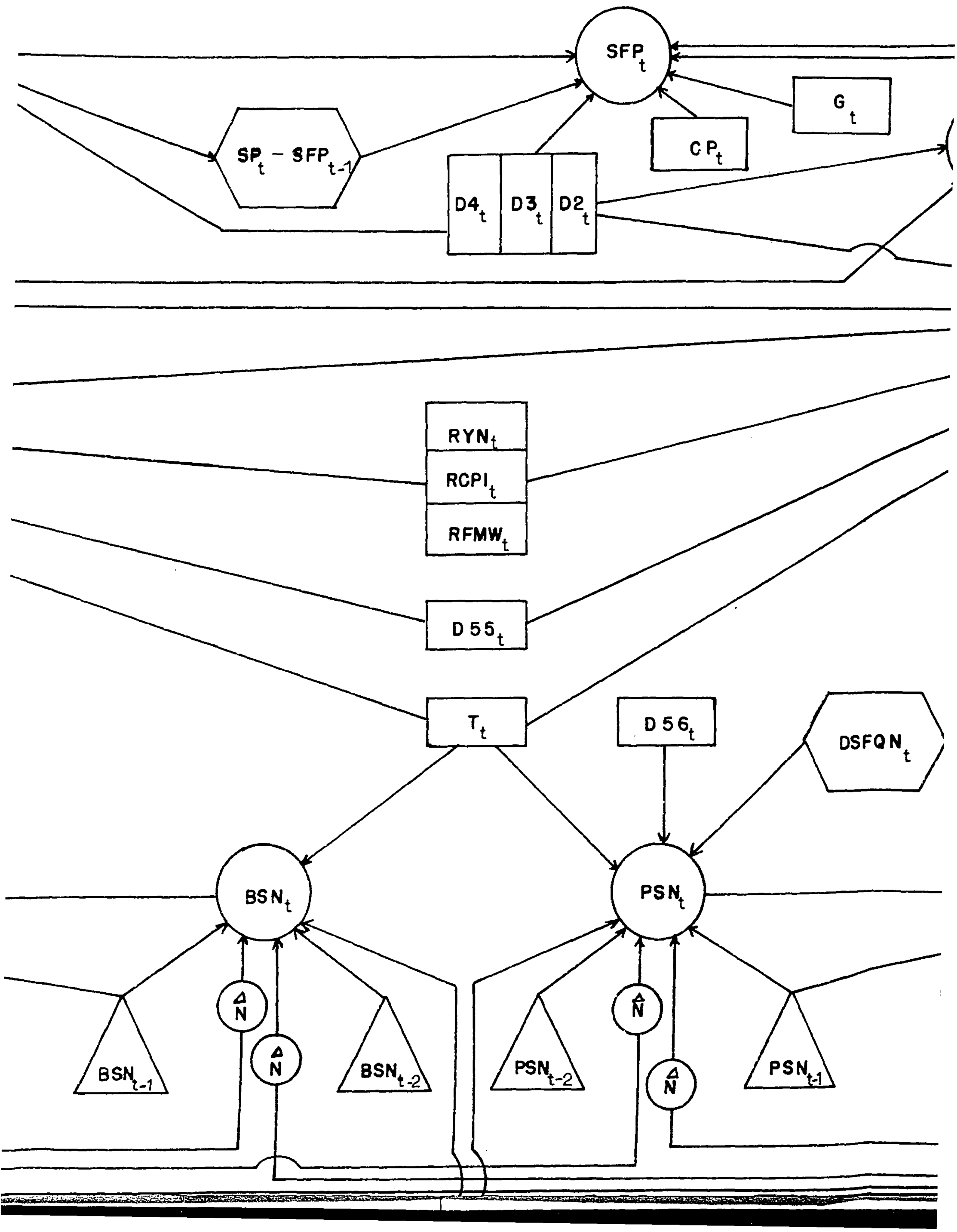
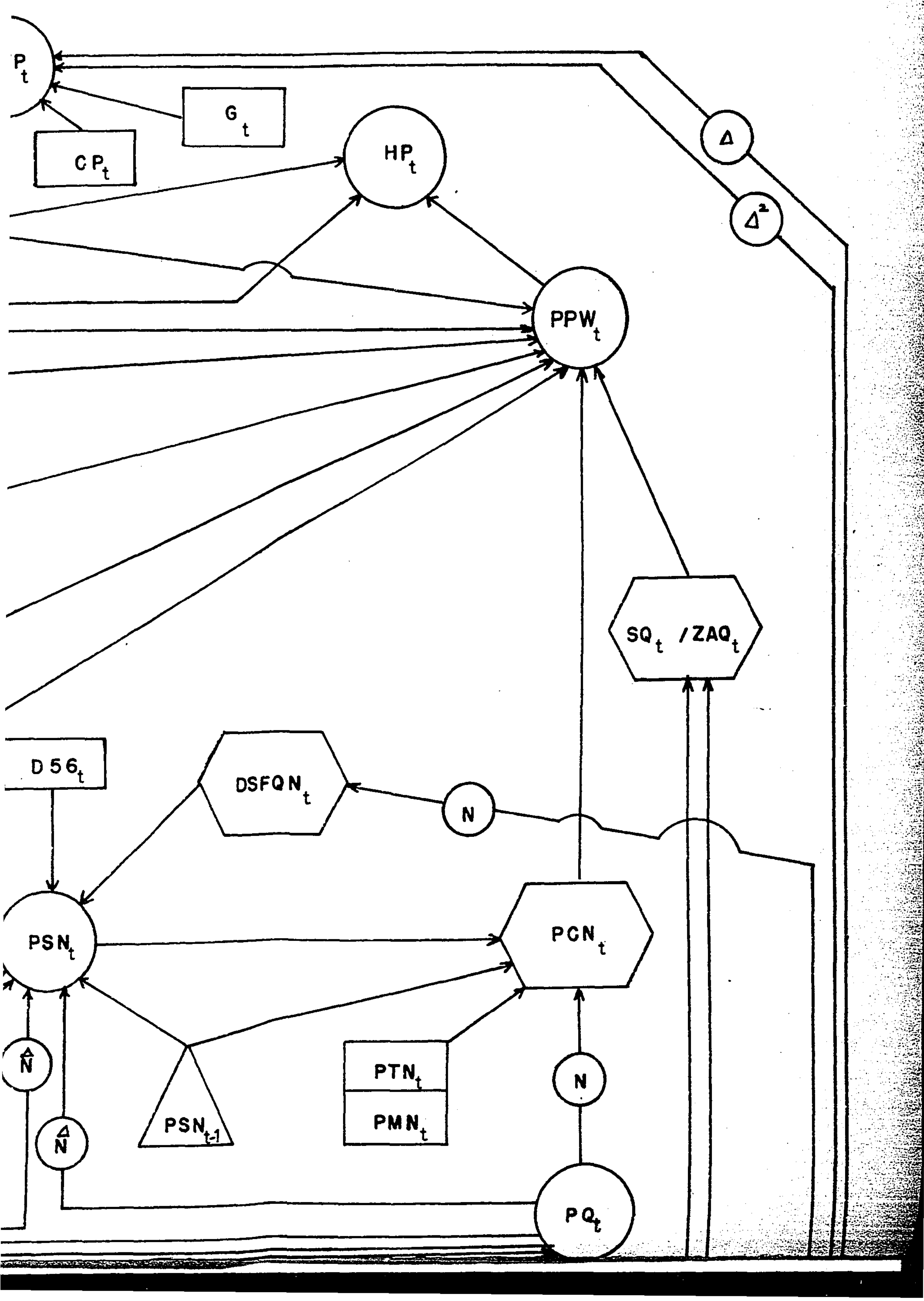
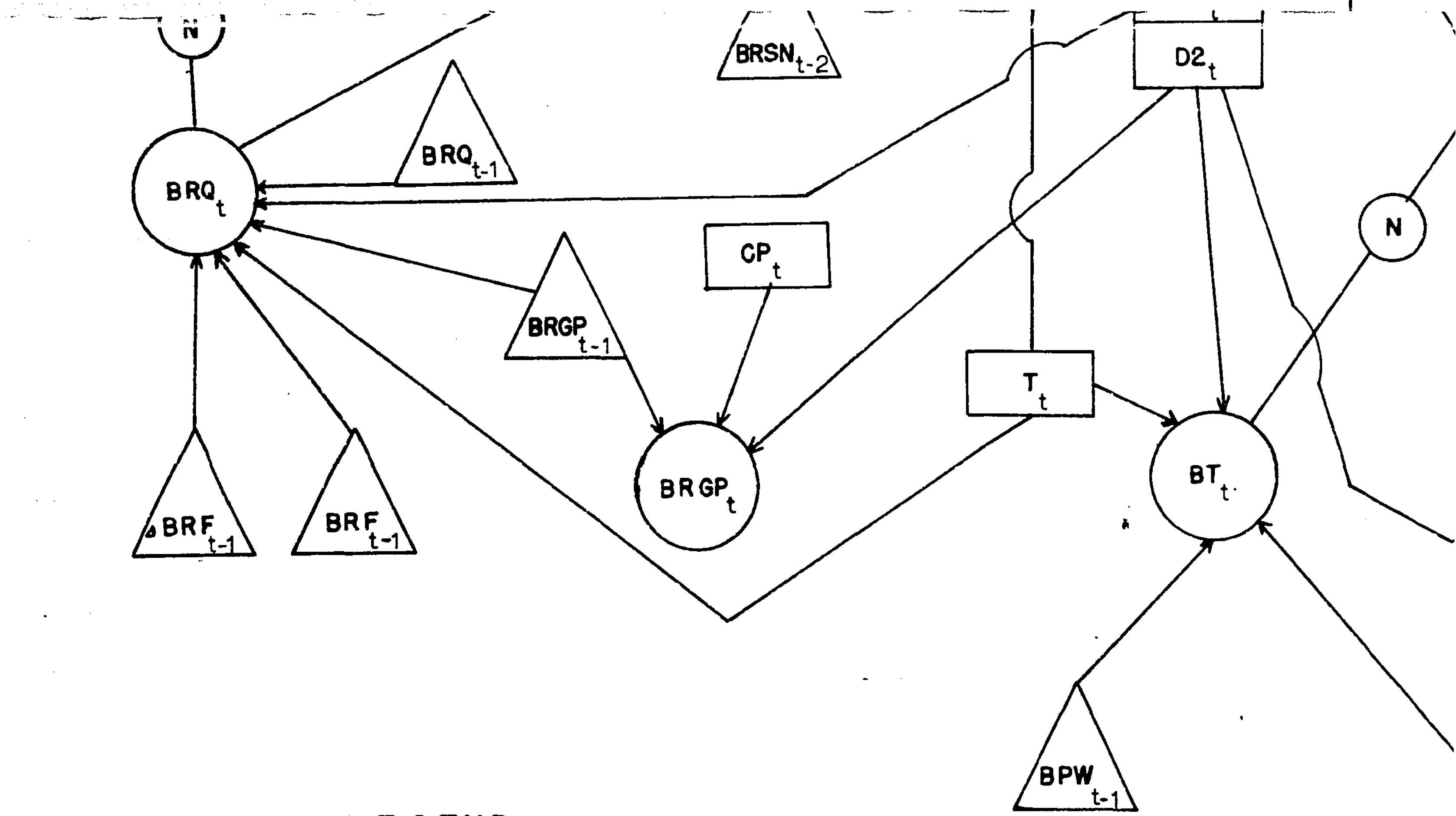
$D3_t$
$D2_t$
N
BSN_{t-1}
BQ_t


SFP_t
SP_t - SFP_t-1
D4_t
D3_t
D2_t
CP_t
G_t
RYN_t
RCPI_t
RFMW_t
D 55_t
T_t
D 56_t
DSFQN_t
BSN_t
PSN_t
BSN_t-1
BSN_t-2
PSN_t-2
PSN_t-1
N
N
N
N



P_t
G_t
CP_t
HP_t
Δ
Δ^2
PPW_t
SQ_t / ZAQ_t
$D56_t$
$DSFQN_t$
N
PSN_t
PCN_t
$\hat{N}$
$\hat{N}$
PSN_{t-1}
PTN_t
PMN_t
N
PQ_t



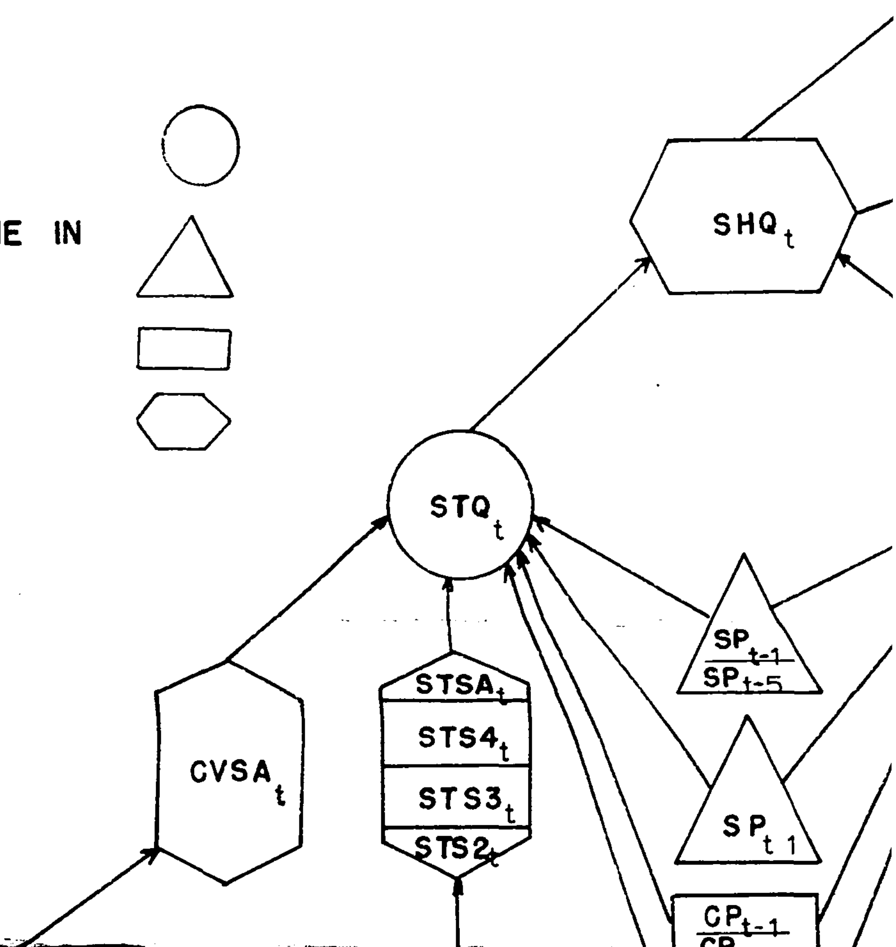
LEGEND

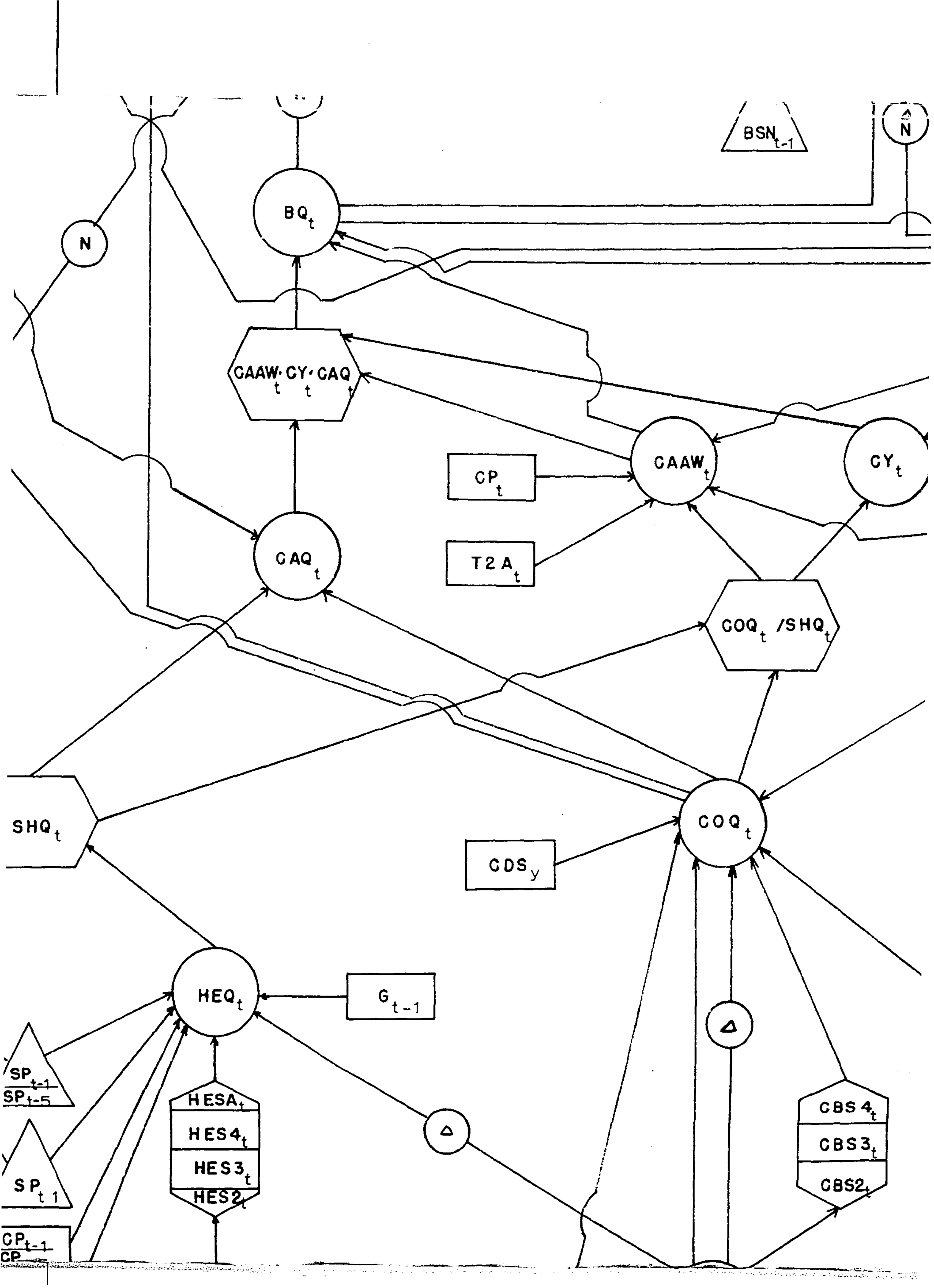
ENDOGENOUS VARIABLES

ENDOGENOUS VARIABLES PREDETERMINE IN OTHER THAN CURRENT PERIODS

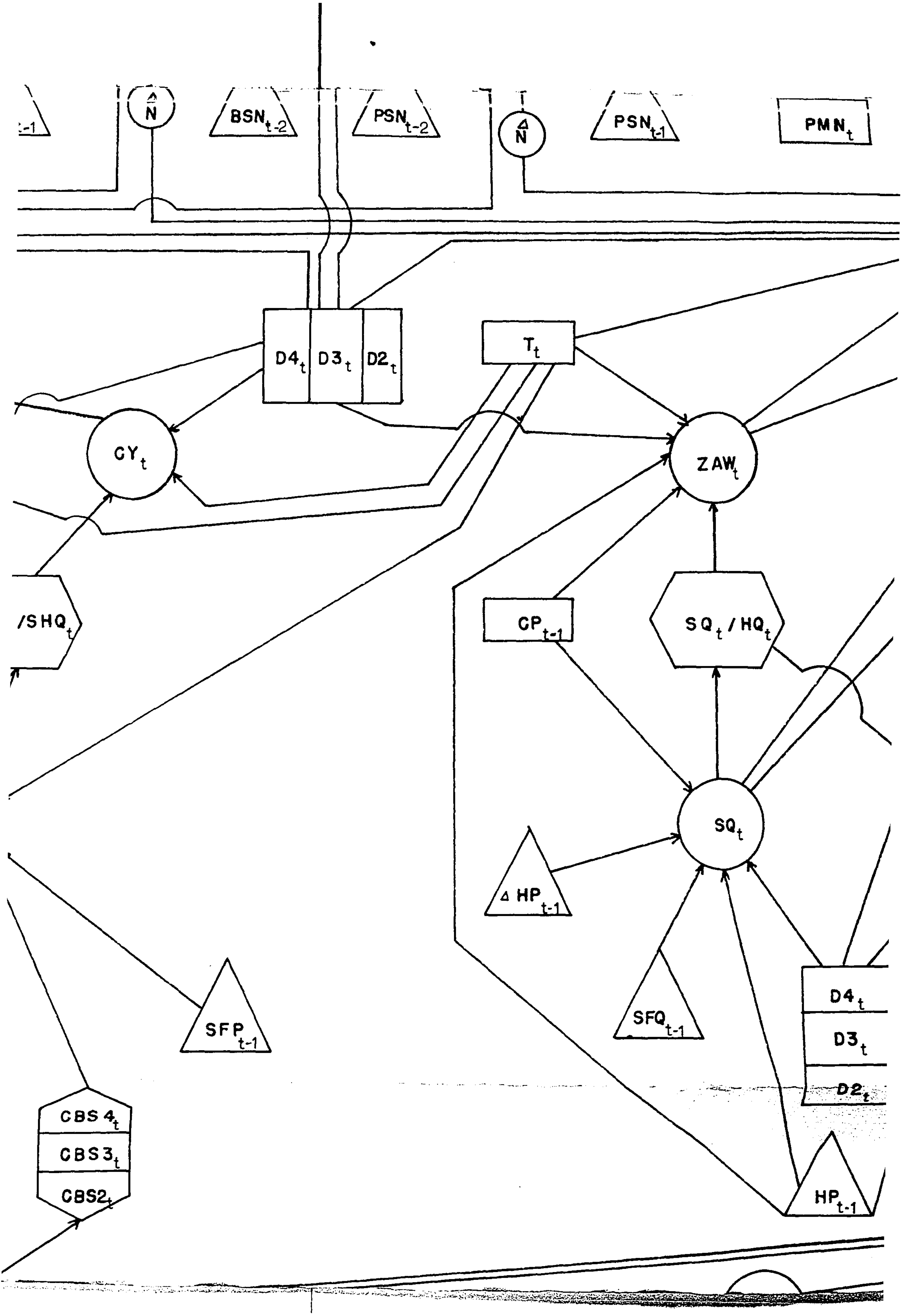
EXOGENOUS VARIABLES

IDENTITY RELATIONSHIPS





N
BQt
BSNt-1
N̂
CAAWt·CYt·CAQt
CAAWt
CYt
CPt
T2At
CAQt
COQt /SHQt
SHQt
COQt
CDSy
HEQt
Gt-1
SPt-1/SPt-5
SPt1
CPt-1/CP
HESAt
HES4t
HES3t
HES2t
CBS4t
CBS3t
CBS2t



t-1
N
BSN t-2
PSN t-2
N
PSN t-1
PMN t
D4 t
D3 t
D2 t
T t
CY t
ZAW t
/SHQ t
CP t-1
SQ t / HQ t
SQ t
Δ HP t-1
SFP t-1
SFQ t-1
D4 t
D3 t
D2 t
CBS 4 t
CBS 3 t
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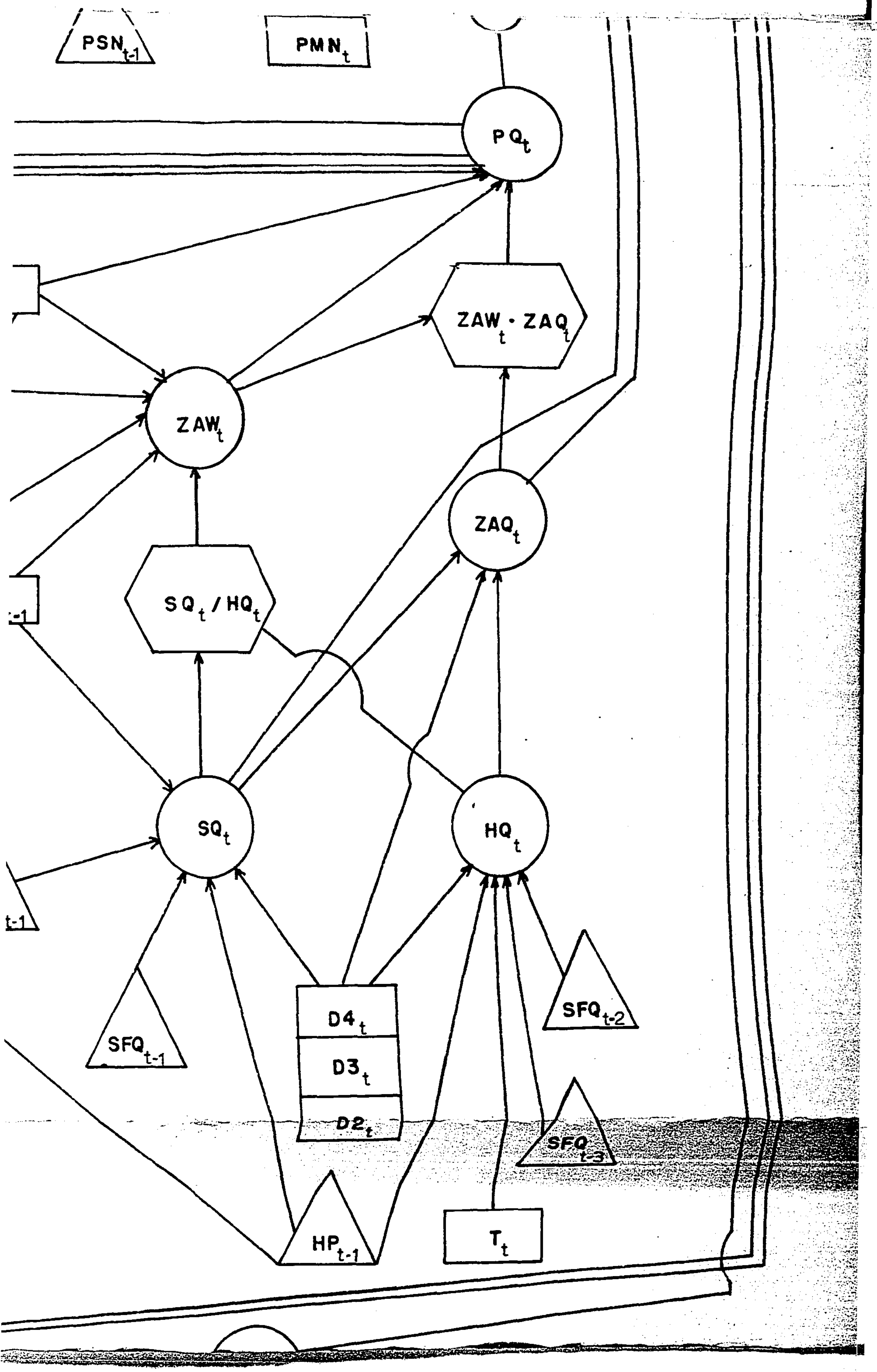
HP t-1



PSN t-1
PMN t
PQ t
ZAW t · ZAQ t
ZAW t
ZAQ t
SQ t / HQ t
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D4 t
D3 t
D2 t
SFQ t-2
SFQ t-3
HP t-1
T t

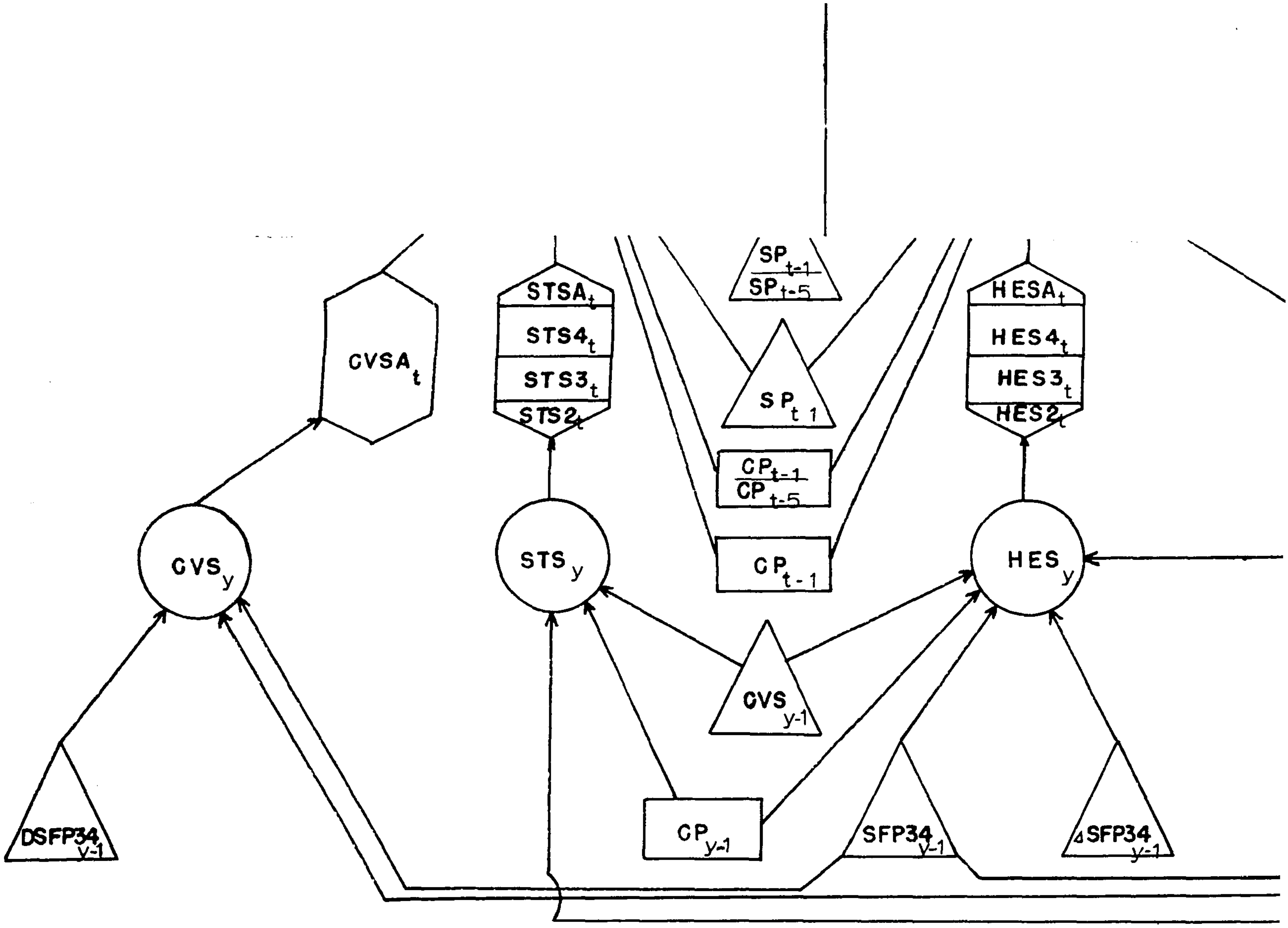
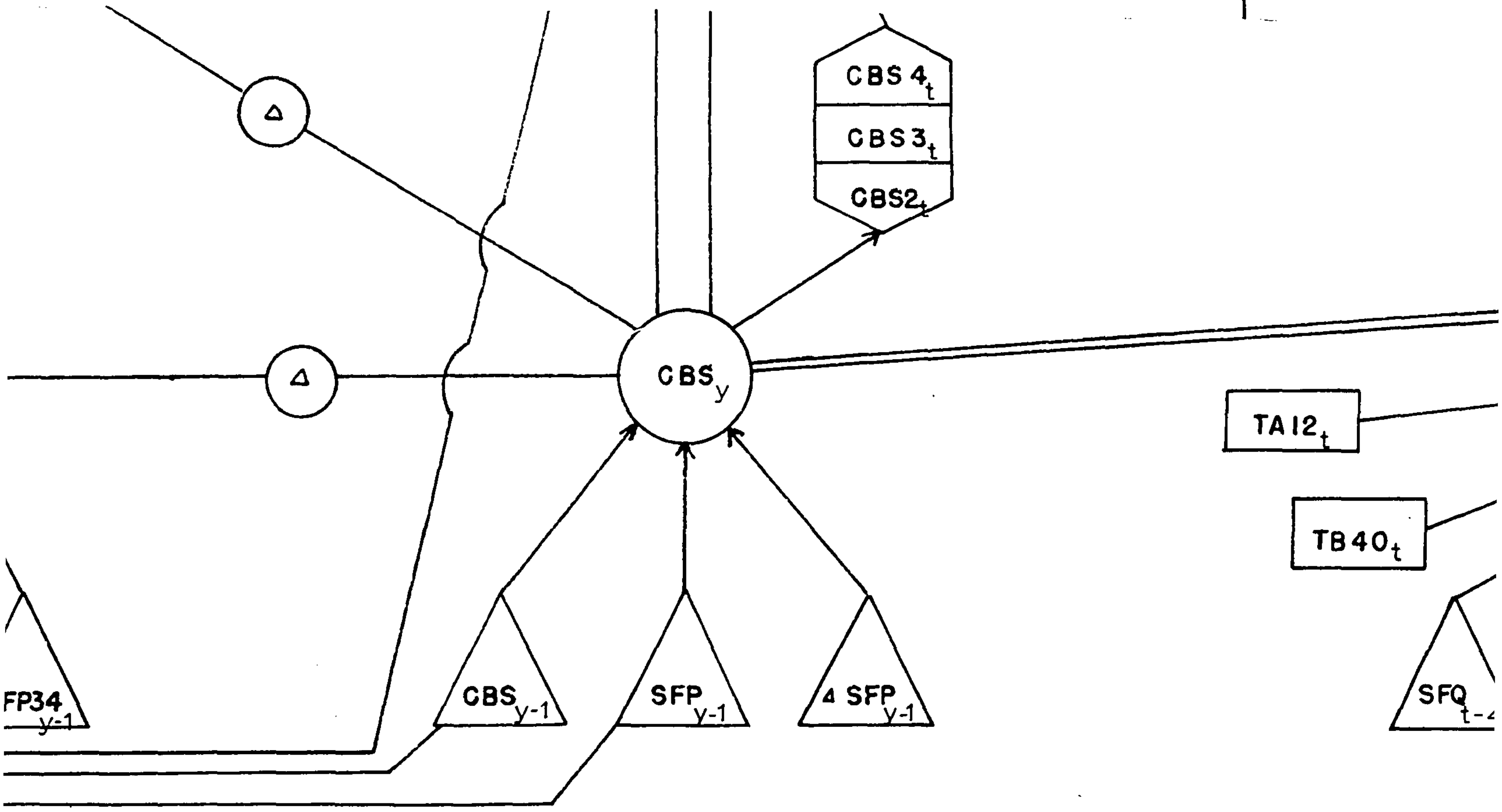
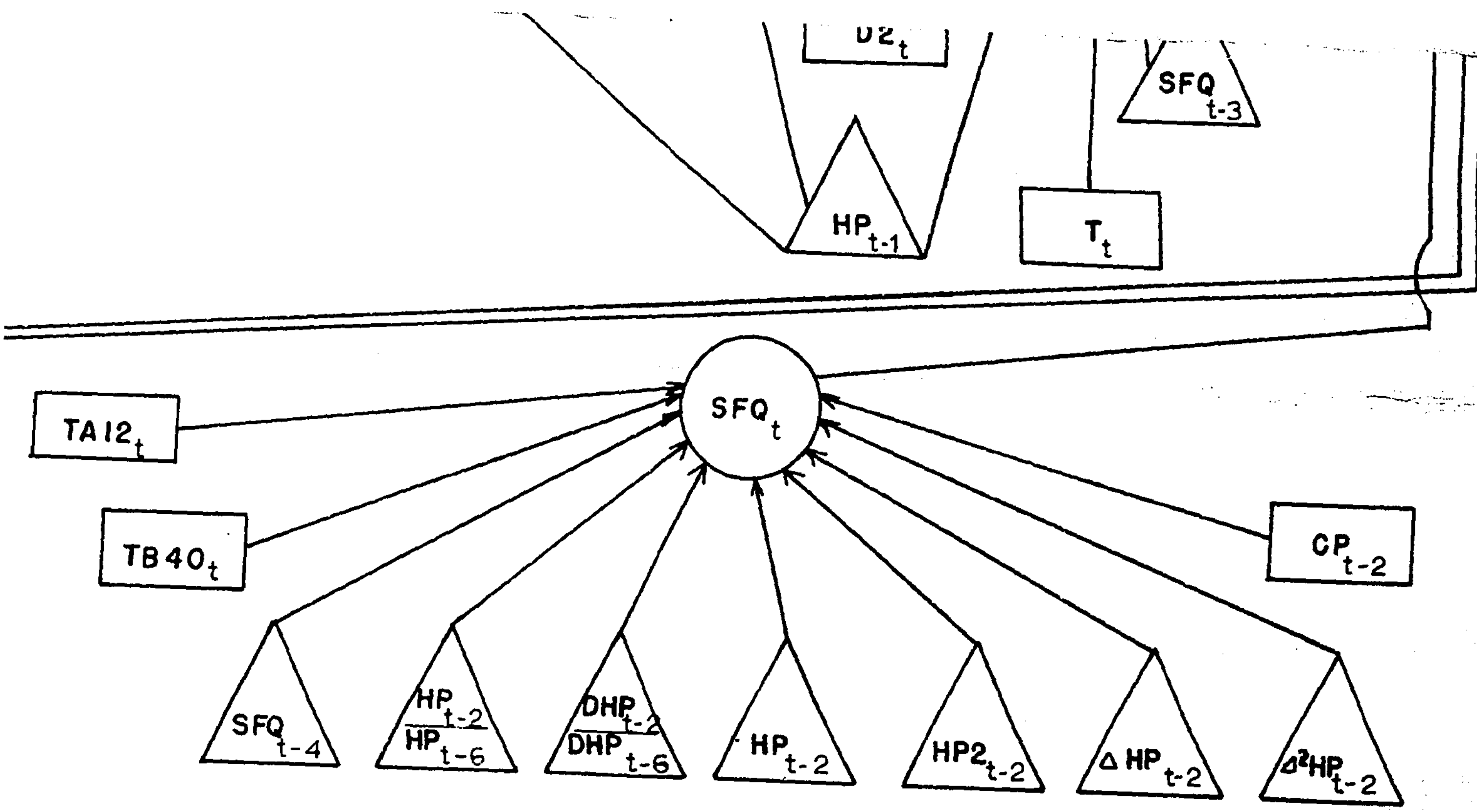


FIGURE 4.2 SCHEMATIC R



TIC REPRESENTATION OF LIVESTOCK M



STOCK MEAT ECONOMY

adequately described by current and past prices (in this context current refers to period t-4).

Sow farrowings at t-2 and t-3 influence the number of barrows and gilts marketed in period t. The number of sows farrowing at t-1 is a major determinant of the marketing of sows at t. The total number of hogs marketed, together with the average dressing weight per head, determines the quantity of pork produced.

The consumption of pork during period t is the summation of the beginning cold storage holdings, minus the ending stocks, plus net foreign trade (imports minus exports), plus current pork production. All variables in this identity are measured on a per capita basis.

Per capita cold storage holdings of pork at the end of period t (PSN_t) are determined by lagged storage stocks of pork, the first differences on pork and beef production and exogenous variables. In this formulation current prices do not directly influence current storage stocks. Hence, all variables in the per capita pork consumption identity are logically determined prior to the estimation of current pork prices.

The wholesale price of pork is determined simultaneously together with the wholesale prices of beef and broilers. It is assumed that the demand and supply forces intersect in the wholesale market with the resulting prices then being reflected in the live animal market. Thus, the price of live hogs can be sequentially determined after the wholesale price has been estimated. The price of market hogs in period t is a major factor in the estimation of farrowings in period t+2.

The estimation of live hog prices completes one full cycle of the sequential structure in the hog sector. The relationships in the beef and broiler sectors follow a similar ordering. The recursive nature of these sectors is evident by again examining Figure 4.2.

Estimation procedure

Economic theory and knowledge of the livestock-meat industry were instrumental in formulating the basic structure of the econometric model. However, to develop an operational model, parameters had to be estimated for the independent variables in each functional relationship. Data availability was a constant restraint in the specification of the empirical model. Ideally, once a "maintained hypothesis" based on economic theory, intuitive knowledge and data considerations is constructed, re-specification of the model should not be necessary. However, in practice the results of empirically testing "maintained hypothesis" number one are used as a base to construct "maintained hypothesis" number two. In this study numerous specifications and testing of the relationships were necessary before a final structure was formulated.

Regression analysis was used to estimate the structural coefficients in the behavioral relationships. In the specification of any particular behavioral relationship, it is impossible to identify and quantify all causal variables. In regression analysis all imperfections in the specification of the equation are included in the residual error term. The valid use of least squares regression depends on this disturbance being normally distributed with an expectation of zero. In Chapter III several reasons were outlined why the random error assumption may be invalid.

In this study least squares regression was used in the initial estimation stage. Once a final "maintained hypothesis" was accepted, the residuals of each equation were tested for autocorrelation. The Durbin-Watson d statistic indicated that the error terms of most equations were significantly autocorrelated. An estimated ρ was calculated for each equation from the Durbin-Watson d statistic. The variables in each equation were transformed by the estimated ρ value. Least squares regression was applied to the new variables. The d statistic was re-calculated. The new value of ρ was used to again transform the data. The process of estimation and testing was carried out until the Durbin-Watson d statistic reached the value 2.00, or in the case of several equations, until it was evident that it was not possible to achieve this value under the assumption of a first-order autoregressive scheme.

In the late stages of the project, a first-order autoregressive least squares computer model was available. Those equations containing lagged regressand variables were re-estimated by this technique. In addition, any further estimation of coefficients necessitated by re-specification of equations was done exclusively by the least squares and autoregressive models.

In general the results are only reported for that estimation scheme yielding the coefficients used in the simulator model. The estimation technique employed can be ascertained by examining the ρ value. This statistic is zero when the corresponding equation was estimated by least squares. Equations estimated by first transforming the data by a calculated ρ have a nonzero ρ value with no associated t statistic. Autoregressive least squares estimates have both a nonzero ρ and t statistic.

The t statistic is written below the associated regression coefficients. Because of the "trial and error" method of determining the most appropriate specification of each equation, the t statistic can only be considered a guide to a variable's significance in a particular equation. For this reason no designation is made as to the particular significance level within which a given t statistic falls.

Empirical Results

Meat inventories

Current and one-period lagged inventories of beef, pork and broilers form an integral part of the associated consumption identities. The specification of the meat inventory equations retains the recursive ordering of the model.

A minimum stock of meat is necessary for the normal functioning of the meat industry. The seasonality of meat production and the associated changes in price give an impetus to accumulate stocks beyond the day-to-day requirements. These stocks are held in anticipation of yielding a profit from the seasonal price structure. A comprehensive theory relating to meat inventories, together with parameter estimates for beef and pork, was put forward by Fuller (25) and Fuller and Ladd (26). The expectations of meat wholesalers are transformed into quantifiable variables, not including current price. The specification of the beef, pork and broiler inventory equations in this study is based on these findings.

It is assumed that the "pipeline" component of meat inventories bears a constant relationship to the domestic population. Hence, to explain the variation net of population growth, the end of quarter inventory equations are estimated on a per capita basis.

Beef cold storage holdings are explained by the following equation:

$$\begin{aligned} BSN_t = {} & .2368 + \underset{(6.18)}{1.099}BSN_{t-1} - \underset{(-2.17)}{.3504}BSN_{t-2} + \underset{(3.77)}{.1107}\Delta BQN_t \\ & + \underset{(2.14)}{.0439}\Delta PQN_t + \underset{(0.49)}{.0388}D4_t - \underset{(-0.27)}{.0332}D3_t - \underset{(-1.69)}{.1424}D2_t \\ & + \underset{(1.46)}{.0017}T_t \\ & S = .106 \qquad R^2 = .846 \qquad \rho = \underset{(-0.57)}{-.136} \qquad d = 2.08 \end{aligned} \tag{4.1}$$

The accelerator principle is invoked through the inclusion of one and two period lagged inventories. The dummy variables $D4_t$, $D3_t$ and $D2_t$ permit the intercept to vary by quarter. For example, the intercept coefficient for the fourth quarter is .2756 (.2368 + .0388), while for the third quarter it is .2036. The t statistic for the coefficient of $D4_t$ tests the hypothesis that the intercept for the fourth quarter is significantly different from that for the first quarter. Insufficient information is given in Equation 4.1 to test hypotheses concerning the quarterly or over-all intercept coefficients, other than quarterly comparisons with quarter one. The appropriate elements of the inverse matrix $(X'X)^{-1}$ are necessary to conduct further quarterly hypothesis tests.

Cold storage holdings of pork are explained by Equation 4.2.

$$
\begin{aligned}
PSN_t = {} & .4018 + \underset{(13.3)}{1.209PSN_{t-1}} - \underset{(-6.15)}{.4744PSN_{t-2}} + \underset{(1.09)}{.0460\Delta BQN_t} \\
& + \underset{(5.12)}{.1683\Delta PQN_t} + \underset{(4.62)}{41.28DSFQN_t} - \underset{(-2.33)}{.3947D4_t} - \underset{(-5.03)}{.6746D3_t} \\
& + \underset{(0.44)}{.0701D2_t} + \underset{(2.29)}{.0058T_t} + \underset{(1.64)}{.1567D56_t} \\
& S = .158 \quad R^2 = .956 \quad \rho = \underset{(-4.57)}{-.565} \quad d = 1.97 \qquad (4.2)
\end{aligned}
$$

Pork stocks are influenced by the same type of variables as are beef inventories except for the inclusion of variable $DSFQN_t$ and an additional dummy variable.

The meat inventory study of Tolley and Harrell (81) indicated that packers used the Department of Agriculture "Pig Crop Report" when making their decisions concerning inventory accumulation. On the basis of this conclusion, Fuller and Ladd (26) included spring minus fall farrowings in the specification and estimation of their pork cold storage holdings equation. In this study the per capita difference in farrowings enters the model during the first and fourth quarters when inventories are normally increasing.

The dummy variable $D56_t$ is included to account for the large reduction in pork inventories which started in late 1956. The intercept term for the second quarter 1953 to the fourth quarter 1956 is thus .5585 plus the coefficient for the relevant quarterly dummy variable.

Equation 4.3 is used to predict storage stocks of broiler meat.

$$\begin{aligned} BRSN_t = {} & .0524 + \underset{(6.55)}{1.134BRSN_{t-1}} - \underset{(-3.98)}{.6128BRSN_{t-2}} + \underset{(1.20)}{.0093\Delta BRQN_t} \\ & + \underset{(2.48)}{.0102\Delta PQN_t} + \underset{(1.18)}{.0226D4_t} + \underset{(2.20)}{.0459D3_t} + \underset{(0.80)}{.0160D2_t} \\ & S = .017 \quad R^2 = .655 \quad \underset{(-1.82)}{\rho = -.423} \quad d = 2.25 \end{aligned} \tag{4.3}$$

<u>Cattle inventories</u>[1]

The January 1 inventories of cows, steers and heifers are used in the estimation of the slaughter of these respective classes of cattle during the succeeding year. The corresponding inventory of beef calves is a major determinant of the numbers of steers and heifers on farms at the beginning of the following year. The cow inventory is de-limited into beef and dairy cows. The latter category is treated as exogenously determined in this analysis. That is, it is assumed that the dairy cow inventory is not influenced by feed grain or livestock prices. Inventory equations are formulated and empirically estimated for the four remaining classes of cattle; namely, beef cows, steers, heifers and calves.

In the past the number of cattle on farms has followed a distinct cyclical pattern -- a complete cycle taking from 10 to 14 years. Starting at the "trough" of the inventory cycle, cattle numbers

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[1]The specifications of the beef cattle inventory equations were influenced to a considerable extent by the work of Walters (105).

increase faster than the equilibrium growth rate. This period usually parallels the end of a period of very favorable cattle prices. Inventories are increased by adding cows to the basic breeding herd through a decreased cull rate and increased retention of replacement heifers. As well, feeder cattle are often fed to heavier market weights. The gradual increase in production eventually exceeds the increasing demand, and first slaughter prices and then feeder prices begin to decrease.

A point is reached where the cattle producers' outlook becomes pessimistic. The now less profitable breeding herds are decreased by selling cows and retaining a smaller than normal percentage of replacement heifers. Initially, feeder cattle are likely to be held off the market in anticipation of better prices. Eventually, the withheld feeder cattle must be marketed. The reduction in basic herds, together with the abnormally high marketings of finished animals at excessive weights, subject the already overburdened market to even greater pressures.

Cows on farms continue to decrease in response to the market price signal. Correspondingly, operating at about a 2 year lag, marketings of steers and heifers eventually become less than an equilibrium level. Prices level off and again begin to increase. Cattle breeders become more and more aware of the industry's increasing profitability. The reduction in the cow inventory is halted and accumulation again takes place.

<u>Cow inventory</u> Each year the beef calf producer must determine whether his best alternative is to sell cows directly for income or to retain them for the income they yield through rearing calves. Hence, the anticipated price of feeder calves is a major determinant of the beef cow inventory. Where the feeder calf price indicates a reduction in the cow inventory is desirable, the de-accumulation is likely to take place in a systematic manner. The cull rate will be increased and fewer potential replacement heifers withheld from the market.

On the other hand, if an increase in cow numbers is expected to be more profitable, accumulation can only take place through the reversing of the two processes outlined above. While some additional 18- to 24-month-old heifers may be withheld from the market for breeding purposes, the more common procedure is to reduce the number of 6- to 12-month-old heifer calves sold to feedlots. Thus, in times of either a reduction or accumulation of beef cows, their numbers are likely to be significantly tied to the inventory of the past year.

Beef cows on farms January 1 are estimated by the following equation:

$$CBS_y = -2436 + \underset{(8.62)}{1.155}CBS_{y-1} + \underset{(2.92)}{139.1}SFP_{y-1} - \underset{(-1.84)}{57.88}\Delta SFP_{y-1}$$

$$S = 524 \qquad R^2 = .980 \qquad \rho = \underset{(2.86)}{.648} \qquad d = 1.53 \qquad (4.4)$$

The variable SFP_{y-1} is the average price of feeder calves during the preceding year. It is assumed that the beef calf producer estimates the future profitability of his cow enterprise on the basis of this past price. Equation 4.4 indicates that the beef cow inventory increases 139.1 thousand head for every dollar per hundredweight increase in feeder calf prices.

It was also found that inventories are associated with the direction of change in past feeder calf prices. If the price in period y-1 increases over that in period y-2, the beef cow inventory decreases 57.9 thousand head per dollar change. In times of rising feeder prices, this reflects the biological rigidity preventing cow numbers from increasing as rapidly as the lagged feeder price variable indicates. When prices are falling the significance of this variable may be attributed to rigidities in producer behavior.

Calf inventory The number of calves on farms January 1 is equal to the number born during the preceding year less sales and death loss. Data are not readily available for two of these variables. Hence, rather than estimate the calf inventory as an identity, a behavioral equation is specified and structural coefficients estimated.

The number of calves born each year depends on the number of cows kept for breeding purposes and the fertility rate (number of calves born per 100 cows). Beef cows on farms at the beginning of the year are highly correlated to the number of cows rearing calves during the following year. Hence, the beef cow inventory of year y-1 is used as one variable in the estimation of the beef calf inventory in year y. The coefficient associated with this variable is an estimate of the fertility rate.

The cattle breeder has the alternative of selling calves either as veal or as feeders. In general the higher the price of feeder calves during the latter half of the year, the more likely calves will not be sold as veal.

The January 1 beef calf inventory is estimated by the equation:

$$CVS_y = -1974 + \underset{(6.32)}{.9291CBS_{y-1}} + \underset{(2.04)}{109.4SFP34_{y-1}}$$

$$- \underset{(-0.85)}{19.58DSFP34_{y-1}}$$

$$S = 474 \qquad R^2 = .978 \qquad \rho = \underset{(2.19)}{.695} \qquad d = 1.45 \qquad (4.5)$$

The beef calf inventory was initially fitted to the lagged beef cow inventory and the average price of feeder calves for the last half of the previous year. Examination of the residuals indicated that the influence of the latter variable was not the same at high and low prices. Hence, the variable $DSFP34_{y-1}$ was constructed such that the feeder calf price entered the model when its value was less than $24.00 per hundredweight. The results of Equation 4.5 indicate that the beef calf inventory increases 109.4 thousand head when the average feeder price for the last half of the preceding year increases $1.00 per hundredweight and is greater than $24.00, but correspondingly increases 89.8 thousand head when the associated feeder calf price is less than $24.00 per hundredweight.

<u>Steer and heifer inventories</u> January 1 inventories of steers 1 year and older and heifers 1 to 2 years old are drawn from the pool of calves 1 year old or less on farms at the beginning of the preceding year. The number drawn from this pool and kept rather than slaughtered

depends on the expected returns from slaughter at a future date compared to the expected costs of further feeding.

The price of finished cattle represents the expected returns from keeping steers. The cost of finishing steers depends mainly on anticipated feed prices. It is assumed that feed price forecasts are highly influenced by past corn prices.

Equation 4.6 is assumed to represent the structure by which the steer inventory is determined.

$$STS_y = -3156 + \underset{(8.63)}{.5182CVS_{y-1}} + \underset{(5.85)}{118.5SFP_{y-1}} - \underset{(-0.39)}{246.4CP_{y-1}}$$

$$S = 335 \quad R^2 = .964 \quad \underset{(-0.33)}{\rho = -.159} \quad d = 1.67 \qquad (4.6)$$

The parameter estimate for lagged beef calves indicates that every additional beef calf on farms the previous January 1 increases the current steer inventory by .518 head. Male dairy calves not sold for veal are included in the steer inventory. Hence, the coefficients of Equation 4.6 implicitly account for any such calves.

One- to 2-year-old beef heifers are kept either for slaughter as finished animals or for additions to the beef cow herd. Hence, a somewhat different set of variables determines the heifer inventory compared to the steer inventory. Equation 4.7 is used to estimate the January 1 beef heifer inventory.

$$HES_y = -1498 + \underset{(13.0)}{.3381CVS_{y-1}} + \underset{(2.05)}{722.0CP_{y-1}} + \underset{(5.46)}{.3560\Delta CBS_y}$$

$$+ \underset{(1.91)}{26.16SFP34_{y-1}} - \underset{(-0.50)}{6.581\Delta SFP34_{y-1}}$$

$$S = 114 \quad R^2 = .990 \quad \rho = 0 \quad d = 2.03 \qquad (4.7)$$

The first difference of the beef cow inventory indicates the position of the cattle cycle. When beef cow numbers are increasing, more 1- to 2-year-old heifers are retained for breeding purposes. The price of feeder calves gives an indication of the profitability of increasing cattle production. If this price is high in the fall of the year, more heifers are bred to produce calves the following spring and hence are on farms at the census period. The first difference of the fall feeder price is included as an additional measure of potential earnings from either breeding heifers or selling as slaughter animals. Equation 4.7 indicates that a one dollar increase in the fall feeder price over the previous year results in 6.5 thousand fewer heifers on farms the following January 1. The negative sign of this variable appears to be in conflict with economic reasoning. However, it can be argued that this variable adjusts for an over-response to fall feeder prices when they are rising and conversely in periods when they are declining.

Sows farrowing

The number of hogs slaughtered in the current time period is directly related to the number of sows farrowed some two to three quarters earlier. The decision to farrow is finalized about two quarters before farrowing takes place. However, the basic decision concerning hog production in a given year is made in the preceding fall quarter. Factors influencing the number of sows farrowed include the expected price of hogs at market time, the expected price and supply of feed, the facilities available on farms for raising hogs and the relative profitability of alternative uses for the resources employed in hog production.

Equation 4.8 is assumed to include those variables relevant in the determination of sow farrowings.

$$\begin{aligned} SFQ_t = {} & 576.0 + \underset{(9.92)}{.6085}SFQ_{t-4} - \underset{(-0.62)}{158.3}HP_{t-2}/HP_{t-6} \\ & - \underset{(-0.52)}{27.84}DHP_{t-2}/DHP_{t-6} - \underset{(-2.06)}{592.5}CP_{t-2} + \underset{(2.92)}{57.51}HP_{t-2} \\ & + \underset{(4.57)}{50.37}HP2_{t-2} - \underset{(-1.66)}{50.40}\Delta HP_{t-2} + \underset{(2.31)}{36.82}\Delta^2 HP_{t-2} \\ & - \underset{(-2.15)}{29.81}TA12_t + \underset{(1.03)}{48.21}TB40_t \\ & S = 163 \quad R^2 = .986 \quad \rho = .420 \quad d = 2.02 \end{aligned} \tag{4.8}$$

It is assumed that expectations concerning future hog and corn prices are determined on the basis of past and present price experiences. Hence, corn and hog prices in period t-2, when the decision to farrow is culminated, are included in a number of different forms in this equation. One such variable is the ratio of hog prices in the decision period to those of the same quarter a year earlier. The net response to this price ratio is given by the coefficients of the second and third explanatory variables of Equation 4.8.[1] For example, in the first through third quarters sow farrowings decrease 186.1 thousand head (-158.3 - 27.84) for a one-unit increase in this price ratio.[2] In the fourth quarter the composite coefficient is -74.8 (-158.3 - 3(-27.84)).

The variable $HP2_{t-2}$ allows the direct influence of past hog prices to differ in the second quarter. A one dollar increase in hog prices in the second quarter causes 107.9 thousand more sows to be farrowed in the fall quarter. However, in the other three quarters a one-unit change in lagged hog prices is associated with a 57.5 thousand head change in farrowings.

The variable $TB40_t$ allows the over-all intercept to differ between the fall and other quarters. The variable $TA12_t$ is included to represent the trend to a higher percentage of fall and winter farrowings.

The number of sows farrowing in the corresponding quarter of the previous year is included to measure any institutional rigidities in

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[1]The latter variable was included after examination of the residuals from originally fitting the equation indicated a different coefficient was associated with the former variable in the fourth quarter. The least squares derived coefficients were highly significant for both the original variable and its dummy counterpart. However, after removing the autocorrelation from the estimated errors, the sign of the dummy variable changed and the t values associated with both variables became insignificant.

[2]Specifically, this would involve a doubling of the price from the past year. Variations in this variable are likely to be relatively small.

hog production. For example, the availability of equipment and buildings is represented by this variable.

Livestock slaughter

Barrow and gilt slaughter Hog production is predetermined once farrowing takes place. Current hog prices influence the number of hogs produced only to the extent of slightly altering the optimal time of marketing. The recursive ordering of the model is retained by assuming that this effect is adequately represented by lagged hog price.

Commercial slaughter of barrows and gilts is estimated by the following equation:

$$HQ_t = 1463 - \underset{(-4.20)}{104.6HP_{t-1}} + \underset{(8.61)}{1.772SFQ_{t-2}} + \underset{(10.8)}{2.704SFQ_{t-3}}$$

$$+ \underset{(3.59)}{3110D4_t} + \underset{(1.79)}{1073D3_t} + \underset{(6.15)}{4219D2_t} + \underset{(15.0)}{63.86T_t}$$

$$S = 542 \qquad R^2 = .9838 \qquad \rho = -.667 \qquad d = 2.04 \qquad (4.9)$$

Equation 4.9 indicates that hog slaughter increases by 1.77 and 2.70 head for every additional farrowing in periods t-2 and t-3, respectively. The sum of these two coefficients can be interpreted as the average number of hogs per litter sold through commercial channels over the period.

The trend variable is included to measure the tendency to larger litter size. Seasonality in hog marketings is represented by the dummy intercept variables.

Sow slaughter The number of sows marketed is contingent upon past farrowings and the expected profitability of the hog industry for the coming year. The following equation estimates commercial sow slaughter:

$$SQ_t = -1225 + \underset{(15.9)}{.8345SFQ_{t-1}} - \underset{(-1.23)}{83.46D4_t} - \underset{(-3.67)}{488.0D3_t}$$

$$+ \underset{(4.56)}{267.1D2_t} + \underset{(4.96)}{848.2CP_{t-1}} - \underset{(-2.71)}{24.94HP_{t-1}} + \underset{(2.23)}{28.75\Delta HP_{t-1}}$$

$$S = 132 \quad R^2 = .9707 \quad \rho = .185 \quad d = 1.99 \qquad (4.10)$$

One-quarter lagged corn and hog prices and the lagged first difference of hog prices indicate the desirability of either selling or re-breeding sows. When corn price increases by one dollar per bushel, sow slaughter increases by 848.2 thousand head, reflecting the decreased potential profit from raising hogs at high corn prices. On the other hand, slaughter decreases 24.9 thousand head when lagged hog price increases one dollar per hundredweight. The positive coefficient on the lagged first difference variable may be explained by producers anticipating the opposite direction of price movements about a year later when hogs from the sows in question would be ready for market.

Steer slaughter Steers slaughtered during any given year are basically drawn from the January 1 steer inventory. However, some animals classified as calves at the beginning of the year reach maturity and are marketed subsequent to the year end. Others may be prematurely slaughtered because of unfavorable market prospects.

Quarterly commercial steer slaughter is estimated by the following equation:

$$STQ_t = \underset{}{497.9} + \underset{(1.98)}{485.8CP_{t-1}} - \underset{(-3.13)}{40.29SP_{t-1}} + \underset{(2.26)}{.1534STSA_t}$$

$$- \underset{(-1.06)}{.0065STS4_t} + \underset{(4.69)}{.0281STS3_t} + \underset{(3.33)}{.0179STS2_t}$$

$$+ \underset{(2.72)}{.0976CVSA_t} - \underset{(-1.80)}{663.2CP_{t-1}/CP_{t-5}} + \underset{(1.43)}{373.1SP_{t-1}/SP_{t-5}}$$

$$S = 131 \qquad R^2 = .918 \qquad \rho = .116 \qquad d = 1.91 \qquad (4.11)$$

Since cattle inventories are estimated annually and slaughter quarterly, special variables are constructed to integrate the two time dimensions. The quarterly classification of months outlined earlier grouped December, January and February into the first quarter of the year. Hence, some steers slaughtered during the first quarter are not on farms January 1.

Variable $STSA_t$ is constructed such that the current annual steer inventory, STS_y, is used for the second through fourth quarters, but the first quarter value is one-period lagged inventory, STS_{y-1}. Variable $CVSA_t$ is analogously constructed from the first of the year beef calf inventory.

Variables $STS4_t$, $STS3_t$ and $STS2_t$ are included to allow the influence of variable $STSA_t$ to vary by quarter. Hence, for every thousand head increase in the January 1 steer inventory, slaughter increases 153, 171, 182 and 147 head during the first through fourth quarters, respectively.

One-period lagged steer and corn prices are included to measure the short-run price effect. When corn price in period t-1 is high, producers do not feed cattle to as great a degree of finish. Hence, marketings are greater in the following time period. Equation 4.11

indicates that marketings increase 48.5 thousand head for every 10 cent increase in lagged corn price. On the other hand, when one-period lagged finished steer price is high, the feeding program is accelerated with consequently more cattle being marketed in that quarter and correspondingly fewer in the next quarter.

The ratio of corn and steer prices in period t-1 to those in t-5 represents the longer run profitability of raising steers to maturity. In periods of rising corn prices the ratio CP_{t-1}/CP_{t-5} is increasing, and hence current marketings decline because of a higher than normal proportion of animals being sold in the previous quarters. The opposite argument holds when the ratio SP_{t-1}/SP_{t-5} increases.

Heifer slaughter The quarterly slaughter of 1- to 2-year-old beef heifers is a function of the same general type of variables as steer slaughter. However, heifers counted in the January 1 inventory may be kept for replacements or additions to the beef cow herd rather than slaughtered. The first difference on the beef cow inventory is included as an explanatory variable in Equation 4.12 in an attempt to measure this facet of the heifer inventory.

$$
\begin{aligned}
HEQ_t = {} & 109.3 - \underset{(-6.83)}{923.1}CP_{t-1} - \underset{(-1.12)}{4.648}G_{t-1} + \underset{(1.80)}{13.94}SP_{t-1} \\
& + \underset{(6.71)}{.2474}HESA_t + \underset{(5.99)}{.0299}HES4_t + \underset{(0.86)}{.0035}HES3_t - \underset{(-2.46)}{.0091}HES2_t \\
& - \underset{(-2.14)}{.0522}\Delta CBS_y + \underset{(3.09)}{571.0}CP_{t-1}/CP_{t-5} - \underset{(-0.32)}{46.24}SP_{t-1}/SP_{t-5} \\
& S = 64.2 \quad R^2 = .964 \quad \rho = \underset{(2.26)}{.368} \quad d = 1.73 \qquad (4.12)
\end{aligned}
$$

Because of the potential use of heifers for breeding purposes, the coefficients of the one-period lagged prices of corn and finished steers and the corresponding price ratio variables are opposite in sign to the same variables in the steer slaughter equation. For example, in periods of generally increasing corn prices, more than the normal proportion of heifers are slaughtered in the current quarter because of fewer being kept for additions to the beef cow herd.

Cow slaughter The slaughter of dairy cows is assumed independent of feed and livestock prices. Hence, it is treated as exogenously given in this study. Data are not available for commercial cow slaughter disaggregated into its beef and dairy components. Based on the work of Crom (8), it is assumed that 22.5 percent of dairy cows on farms January 1 are marketed in the following year. Hence, estimated quarterly beef cow slaughter is calculated as:

$$CBQ_t = COQ_t - .05625CDS_y \qquad (4.13)$$

The behavioral equation used to estimate beef cow slaughter is:

$$\begin{aligned} CBQ_t = 679.2 &- \underset{(-1.37)}{.0639\Delta CBS_y} - \underset{(-2.38)}{31.75SFP_{t-1}} \\ &- \underset{(-2.68)}{28.21SFP34_{y-1}} + \underset{(0.56)}{.0251CBS_y} + \underset{(4.12)}{.0425CBS4_y} \\ &+ \underset{(2.92)}{.0299CBS3_y} - \underset{(-4.00)}{.0089CBS2_y} - \underset{(-1.22)}{10.63T_t} \\ &S = 158 \quad R^2 = .877 \quad \rho = \underset{(1.48)}{.255} \quad d = 1.88 \end{aligned} \qquad (4.14)$$

The variable $SFP34_{y-1}$ measures the annual average price of feeder calves during the year previous to the quarter for which slaughter is estimated. This variable enters the model only during the third and fourth quarters -- the period when the major decision to slaughter or retain cows is made.

A certain percentage of the beef cow herd is culled each quarter regardless of economic conditions. The January 1 beef cow inventory is included to measure this biological phenomenon. The average quarterly culling rates for the first through fourth quarters, respectively, are 2.51, 1.62, 5.50 and 6.76 percent of January 1 beef cow numbers.

The first difference of the beef cow inventory is included to measure the tendency to slaughter fewer beef cows in years of inventory accumulation. The increasing life cycle of beef cows and hence generally lower slaughter rate is indicated by the negative coefficient on the trend variable.

Total commercial cow slaughter is determined by substituting Equation 4.14 into 4.13. Hence,

$$\begin{aligned} COQ_t = {} & .05625CDS_y + 679.2 - .0639\Delta CBS_y - 31.75SFP_{t-1} \\ & - .28.21SFP34_{y-1} + .0251CBS_y + .0425CBS4_y \\ & + .0299CBS3_y - .0089CBS2_y - 10.63T_t \end{aligned} \tag{4.15}$$

Meat production

Pork production The quantity of edible pork produced from a given number of hogs varies according to the average liveweight per head and the dressing yield. Neither of these variables can be treated as strictly exogenous in this study. Both are contingent upon at least one endogenous, predetermined or instrument variable.

The average liveweight of all hogs slaughtered is estimated by the following equation:

$$ZAW_t = \underset{}{88.14} + \underset{(7.88)}{51.55SQ_t/HQ_t} + \underset{(1.66)}{9.979CP_{t-1}} + \underset{(1.63)}{.3338HP_{t-1}}$$

$$- \underset{(-6.70)}{6.620D4_t} - \underset{(-2.09)}{2.858D3_t} - \underset{(-.07)}{.0475D2_t} + \underset{(3.86)}{.3100T_t}$$

$$S = 2.24 \qquad R^2 = .887 \qquad \rho = .574 \qquad d = 2.00 \qquad (4.16)$$

The average weight increases as the proportion of sows marketed increases relative to barrows and gilts. Hogs are marketed at heavier weights in periods of low feed prices and high hog prices. The coefficient for lagged corn price is in conflict with a priori reasoning, the average market weight increasing one pound for every 10 cent increase in period t-1 corn price.

The total number of hogs slaughtered is required to estimate pork production. Equations are not specified for all marketable classes of hogs. Hence, instead of estimating this variable by an identity equation, the following technological equation is used:

$$ZAQ_t = 13.05 + \underset{(338)}{1.004HQ_t} + \underset{(87.5)}{1.003SQ_t} - \underset{(-0.86)}{7.802D4_t}$$

$$+ \underset{(2.55)}{52.69D3_t} + \underset{(1.58)}{15.70D2_t}$$

$$S = 25.7 \qquad R^2 = .9999 \qquad \rho = .499 \qquad d = 2.00 \qquad (4.17)$$

The miscellaneous classes of hogs not estimated in the model are included in total hog numbers through the magnitudes of the coefficients of other variables.

Equation 4.18 estimates total pork production.

$$PQ_t = -63.79 + \underset{(46.2)}{.000558ZAW_t \cdot ZAQ_t} + \underset{(1.08)}{.9209ZAW_t} + \underset{(2.47)}{18.37D4_t}$$

$$- \underset{(-2.59)}{37.41D3_t} - \underset{(-1.49)}{11.82D2_t} + \underset{(4.94)}{4.251T_t}$$

$$S = 21.1 \quad R^2 = .997 \quad \rho = .706 \quad d = 2.00 \qquad (4.18)$$

The results indicate that the average dressing yield over the period of estimation is 55.8 percent. The variable ZAW_t is included as an independent variable aside from its initial inclusion in the equation to measure the increased dressing percentage as average liveweight increases. The positive coefficient for the trend variable represents the tendency to market leaner hogs.

Beef production Total beef production is estimated by the following equation:

$$BQ_t = 73.16 + \underset{(620)}{.00999CAAW_t \cdot CY_t \cdot CAQ_t} - \underset{(-6.54)}{.1138CAAW_t}$$

$$- \underset{(-2.79)}{3.629D4_t} - \underset{(-5.17)}{7.046D3_t} - \underset{(-7.92)}{8.410D2_t}$$

$$S = 2.7 \quad R^2 = .99995 \quad \rho = .151 \quad d = 2.02 \qquad (4.19a)$$

The total number of cattle slaughtered, CAQ_t, cannot be treated as the sum of each component class of cattle since not all of these classes are estimated in the econometric model.[1] Hence, as in the determination of total hog slaughter, a technological equation is specified and estimated such that the omitted class of cattle is

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[1]The slaughter of bulls and stags is not considered. Historically, the slaughter of this class of cattle has varied between .9 and 3.5 percent of total cattle slaughter.

explained by the coefficients of the other variables. Equation 4.19b is used to explain total cattle slaughter.

$$\underset{}{CAQ_t} = -1.559 + \underset{(87.1)}{1.001SHQ_t} + \underset{(107)}{1.050COQ_t} + \underset{(1.66)}{9.746D4_t}$$

$$+ \underset{(6.46)}{38.00D3_t} + \underset{(6.63)}{27.33D2_t}$$

$$S = 11.8 \qquad R^2 = .9993 \qquad \rho = .986 \qquad d = 1.77 \qquad (4.19b)$$

For every cow slaughtered total cattle slaughter increases by 1.05 head. This result indicates that one bull or stag is slaughtered for every cow. The coefficients and associated t statistics for the seasonal dummy variables indicate that the marketing of this omitted class of livestock is more pronounced in the second and third quarters. For example, in the second quarter total slaughter is 25.771 thousand head (-1.559 + 27.33) greater than in the first quarter when the same number of other cattle is marketed.

The beef dressing yield, CY_t, is estimated as an endogenous variable rather than implicitly through the coefficients of other variables as in the pork production equation. The major determinant of this variable is the ratio of cow slaughter to steer and heifer slaughter. Equation 4.20 estimates the dressing yield of commercial cattle slaughter.[1]

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[1]The trend variable was highly significant (t = 5.84) in the least squares estimation of Equation 4.20. The loss of significance under the G.L.S. scheme may be attributed to the presence of significantly autocorrelated errors in the original estimation (d = 0.74).

$$CY_t = 2.982 - \underset{(-15.6)}{7.044COQ_t}/SHQ_t + \underset{(1.92)}{.1222D4_t} + \underset{(6.83)}{.3869D3_t}$$

$$+ \underset{(5.16)}{.3011D2_t} + \underset{(0.009)}{.00037T_t}$$

$$S = .187 \quad R^2 = .956 \quad \rho = .950 \quad d = 1.84 \qquad (4.20)$$

The average liveweight of cattle is estimated by the following equation:

$$CAAW_t = 116.6 - \underset{(-1.21)}{25.56CP_t} - \underset{(-4.51)}{104.2COQ_t}/SHQ_t - \underset{(-2.32)}{10.67D4_t}$$

$$- \underset{(-10.4)}{31.43D3_t} - \underset{(-5.48)}{25.51D2_t} + \underset{(2.10)}{1.460T_t} + \underset{(3.73)}{.3896T24_t}$$

$$S = 7.05 \quad R^2 = .896 \quad \rho = .887 \quad d = 1.81 \qquad (4.21)$$

The empirical findings indicate that the average liveweight decreases as the ratio of cows to steers and heifers slaughtered increases. Preliminary specification and estimation of this equation indicated that the trend was not the same for all quarters. Hence, the dummy variable $T24_t$ is included to allow the trend to differ among quarters. For example, the estimated contributions of trend for the first through fourth quarters of 1955, respectively, are: 13.14, 18.50, 16.06 and 12.84 pounds.

Broiler production Broiler chicken production is a short-term enterprise, the time from hatching to maturity taking about 10 weeks. Hence, unlike the beef industry, inventory relationships are not specified. The behavioral relationship directly estimates the ready-to-cook weight, rather than first estimating the number of broilers produced and then transforming this into pounds of edible broiler meat.

Quarterly broiler production is represented by Equation 4.22.

$$\begin{aligned} BRQ_t = {} & -677.2 - \underset{(-0.52)}{50.79}BRGP_{t-1} + \underset{(2.83)}{36.77}BRF_{t-1} \\ & + \underset{(1.94)}{24.00}\Delta BRF_{t-1} + \underset{(3.73)}{1.037}BRQ_{t-1} - \underset{(-2.30)}{221.1}D4_t \\ & + \underset{(3.76)}{215.9}D3_t + \underset{(4.82)}{231.7}D2_t + \underset{(0.65)}{4.521}T_t \end{aligned}$$

$$S = 72.9 \qquad R^2 = .959 \qquad \rho = \underset{(-0.59)}{-.155} \qquad d = 2.08 \qquad (4.22)$$

In the context of this equation broiler production is initiated in period t-1. Production decisions are based on the then current farm price of broilers and broiler feed. Current production is closely tied to that of the past quarter. In periods of increasing output this variable reflects a limited availability of physical equipment and resources. The trend variable is associated with the tendency to a heavier broiler bird.

Since the price of feed grains make up a significant part of the total price of broiler grower mash, this variable cannot be treated as exogenously determined. The following equation is formulated to predict the quarterly price of broiler grower mash:

$$\begin{aligned} BRGP_t = {} & .9344 + \underset{(4.66)}{.8593}CP_t + \underset{(1.79)}{.2990}BRGP_{t-1} - \underset{(-1.43)}{.0306}D4_t \\ & - \underset{(-2.11)}{.0601}D3_t - \underset{(-1.04)}{.0236}D2_t \end{aligned}$$

$$S = .053 \qquad R^2 = .883 \qquad \rho = \underset{(3.17)}{.603} \qquad d = 1.99 \qquad (4.23)$$

The one-period lagged value of the endogenous variable is included to reflect any long-run change in manufacturing costs aside from the grain input.

Foreign trade in beef

Beef imports were subjected to a distinct change in institutional structure beginning in 1958. Prior to this time American beef imports originated primarily in Argentina and were basically a canned specialty product. In 1958 the Australian and New Zealand agreements to supply the United Kingdom with the bulk of their exportable beef expired. Concomitantly in the United States outdoor eating establishments were rapidly expanding, creating an unprecedented demand for hamburger meat.

The two distinct phases of economic environment led to the use of two equations to estimate the net foreign trade in beef. Equation 4.24 relates to the period up to and including the fourth quarter of 1957, while Equation 4.25 was estimated from 1958 through 1964 quarterly data.

$$BT_t = 78.84 + \underset{(0.21)}{.4308}BPW_{t-1} + \underset{(2.73)}{61.65}D4_t + \underset{(3.01)}{46.64}D3_t$$

$$+ \underset{(0.95)}{13.13}D2_t - \underset{(-1.89)}{.0551}COQ_t$$

$$S = 17.2 \qquad R^2 = .690 \qquad \rho = \underset{(0.78)}{.279} \qquad d = 1.33 \qquad (4.24)$$

$$BT_t = 31.61 + \underset{(0.76)}{3.036}BPW_{t-1} + \underset{(3.40)}{88.76}D4_t + \underset{(5.17)}{85.25}D3_t$$

$$- \underset{(-1.39)}{28.41}D2_t - \underset{(-2.25)}{.1962}COQ_t + \underset{(1.49)}{6.885}T_t$$

$$S = 38.4 \qquad R^2 = .855 \qquad \rho = \underset{(4.90)}{.758} \qquad d = 1.81 \qquad (4.25)$$

The number of cows slaughtered in the current time period is included as an explanatory variable because foreign beef competes mainly in this market. A trend was detected in the relationship for the later period whereas none was evident in Equation 4.24. These findings appear consistent with the observation that beef imports were relatively small and stable in the earlier period, but have expanded since 1958 with the growth in demand for the type of meat which countries like Australia and New Zealand have been able to supply.

Wholesale demand for meat

The per capita consumptions of beef, pork and broilers are given by identity Equations 4.26, 4.27 and 4.28, respectively:

$$BCN_t = BQN_t + BSN_{t-1} - BSN_t + BTN_t - BMN_t \tag{4.26}$$

$$PCN_t = PQN_t + PSN_{t-1} - PSN_t + PTN_t - PMN_t \tag{4.27}$$

$$BRCN_t = BRQN_t + BRSN_{t-1} - BRSN_t \tag{4.28}$$

The military consumption of beef and pork and the net foreign trade in pork are assumed determined independently of the economic structure.[1] Hence, no behavioral equations are specified to estimate their values. The remaining determinants of per capita beef, pork and broiler consumptions are endogenous to the system.

[1]Data of an appropriate time dimension are not available for the foreign trade or military consumption of broiler meat. Hence, $BRCN_t$ measures total consumption including net foreign trade, rather than the civilian consumption component as does BCN_t and PCN_t.

The consumer demand relationships for beef, pork and broilers are represented by Equations 4.29, 4.30 and 4.31, respectively.[1]

$$
\begin{aligned}
BPW_t = {} & 65.08 - 2.504BCN_t - \underset{(-1.84)}{.1698}PPW_t + \underset{(0.93)}{.0830}BRP_t \\
& + \underset{(3.12)}{2.006}RCPI_t - \underset{(-0.97)}{.0082}RYN_t + \underset{(10.5)}{.5096}T_t + \underset{(0.72)}{.0278}BCN4_t \\
& + \underset{(3.62)}{.1312}BCN3_t + \underset{(2.62)}{.0857}BCN2_t - \underset{(1.24)}{42.47}RFMW_t \\
& + \underset{(4.45)}{42.05}COQ_t/CAQ_t + \underset{(1.70)}{2.002}D55_t
\end{aligned}
$$

$$
S = 1.33 \qquad R^2 = .883 \qquad \rho = \underset{(0.93)}{.109} \qquad d = 1.36 \tag{4.29}
$$

$$
\begin{aligned}
PPW_t = {} & 51.81 - \underset{(-1.07)}{.1157}BPW_t - \underset{(-8.36)}{3.254}PCN_t + \underset{(1.13)}{.1192}BRP_t \\
& + \underset{(3.69)}{3.093}RCPI_t + \underset{(1.35)}{.0165}RYN_t + \underset{(1.11)}{.0559}T_t - \underset{(1.05)}{.7962}D4_t \\
& - \underset{(-4.00)}{4.503}D3_t - \underset{(-2.46)}{1.315}D2_t - \underset{(-2.99)}{120.0}RFMW_t + \underset{(0.44)}{3.155}SQ_t/ZAQ_t \\
& + \underset{(3.89)}{4.842}D55_t
\end{aligned}
$$

$$
S = 1.29 \qquad R^2 = .956 \qquad \rho = \underset{(2.12)}{.437} \qquad d = 1.55 \tag{4.30}
$$

---

[1]The wholesale beef price equation was estimated by conditional regression. The a priori specified coefficient for BCN_t (-2.504) represents an own price elasticity of -.77 for the first quarter based on 1955-1957 first quarter averages of price and quantity. Unrestrained estimation of this equation resulted in an over-all price elasticity of -.40 based on the 1955-1957 averages. For the same period Brandow (2) estimated the retail elasticity of demand for beef to be -.95. The a priori specified elasticity was used on the basis that it more adequately reflected the true price-quantity interaction. The estimates of the other coefficients in Equation 4.29 do not differ greatly from the unrestrained regression results. In addition, the general fit of the two equations (as measure by S, R^2 and F) did not materially differ. (For a further discussion related to this equation, see the section on the validation of the structure through the simulation of the historical data, pp. 104, 138.)

$$BRP_t = 7.059 + \underset{(4.07)}{.3478BPW_t} + \underset{(3.24)}{.3423PPW_t} - \underset{(-5.75)}{2.497BRCN_t}$$

$$- \underset{(-1.82)}{1.694RCPI_t} + \underset{(0.12)}{.0012RYN_t} + \underset{(1.16)}{.0759T_t} + \underset{(1.23)}{1.226D4_t}$$

$$+ \underset{(4.60)}{6.290D3_t} + \underset{(5.62)}{3.400D2_t} + \underset{(1.53)}{75.98RFMW_t}$$

$$S = 0.93 \quad R^2 = .938 \quad \rho = \underset{(2.85)}{.518} \quad d = 1.88 \qquad (4.31)$$

The price of each respective class of meat is expressed as a function of its own per capita consumption, the price of the two competing meats, plus several demand shifters. The consumer price index, personal disposable income and food marketing wage variables are used in the form of deviations from trend to circumvent the multicollinearity problem among these variables and also between them and trend.

The prices of beef and pork are for a particular grade and class of cattle and hogs, respectively, based on an average number of all other grades and classes of animals marketed. An increase or decrease in the percentage of either cows or sows marketed upsets the associated average relationship. Hence, the variables COQ_t/CAQ_t and SQ_t/ZAQ_t are included as explanatory variables in the relevant equations.

Examination of the residuals from originally fitting the beef and pork equations led to the inclusion of the dummy variable, $D55_t$. The Korean Conflict and its immediate aftermath undoubtedly helps to explain the over-all shift in these demand curves during the early period of this study.

The variables $D4_t$, $D3_t$ and $D2_t$ in the pork and broiler price equations allow the over-all intercepts to have seasonal variation. In the beef price equation it is assumed that the intercept does not differ among seasons, but rather that the price elasticity of demand for beef differs in each quarter. This is reflected through the inclusion of the variables $BCN4_t$, $BCN3_t$ and $BCN2_t$.

Since personal disposable income, the consumer price index and the food marketing wage rate variables are used in the form of deviations from trend, the consistent change in these variables over time is included in the trend variable, T_t. The respective coefficients of the afore mentioned variables relate only to any changes in the variables which are different from their historical trends. The highly significant trend variable for the wholesale beef price equation reflects the impact of the trend components for personal disposable income, consumer price index and food marketing wage rate all changing in the same direction; but it is also the result of a general shift in consumer tastes towards beef as the general level of incomes rises. On the other hand, the relatively small trend coefficients (with low statistical significance) in the pork and broiler demand equations may be a result of the offsetting shift in tastes away from these commodities as incomes rise.

The estimated coefficients of several variables in each demand relationship are inconsistent with *a priori* judgments and economic theory. Positive coefficients are expected for the residual consumer price index and food marketing wage variables. The first has the "wrong" sign in the broiler equation, while the latter is incorrect in the beef and pork demand equations.

In each equation the coefficients for the prices of competing meats should be positive. In the beef demand equation pork price has a negative coefficient whereas the converse is true in the pork demand relationship. The historical counter-cyclical patterns of beef and pork prices are undoubtedly a significant factor in the realization of these results.[1]

Farm level demand

It is assumed that the price making forces in the livestock-meat economy intersect at the wholesale level with a derived demand then extending to the live-animal market. Farm prices are thus sequentially estimated in this study after the wholesale prices have been established.

Slaughter cattle price The price of choice slaughter steers is estimated by the following equation:

[1]Equations 4.29 and 4.30 were each re-estimated by conditional regression assuming cross elasticities of demand between beef and pork of about +.10. The resulting estimates of the coefficients for the remaining variables in each equation were generally unacceptable. At the same time the statistical fit for each equation became significantly poorer. Hence, Equations 4.29 and 4.30 were used despite the "wrong" cross elasticities of demand between beef and pork.

$$SP_t = -.4517 + \underset{(21.8)}{.6762BPW_t} - \underset{(-2.09)}{1.187FMW_t} + \underset{(1.87)}{.3000D4_t}$$

$$+ \underset{(1.04)}{.1880D3_t} + \underset{(3.48)}{.5616D2_t}$$

$$S = 0.48 \quad R^2 = .964 \quad \rho = \underset{(3.12)}{.483} \quad d = 1.74 \qquad (4.32)$$

The food marketing wage variable is highly correlated with trend. Hence, the coefficient of this variable includes the influence of those forces changing in a consistent pattern over time. The coefficient of this variable may be interpreted as a widening of the margin between wholesale and live-animal prices over time.

<u>Feeder cattle price</u> The price of feeder calves is estimated by Equation 4.33.

$$SFP_t = -9.858 + \underset{(10.7)}{1.150SP_t} + \underset{(2.27)}{.1189G_t} - \underset{(-0.41)}{.6608CP_t}$$

$$- \underset{(-3.50)}{.000706\Delta CBS_y} - \underset{(-0.36)}{.000168\Delta^2 CBS_y} - \underset{(-1.05)}{.4460D4_t}$$

$$- \underset{(-2.00)}{1.160D3_t} + \underset{(2.43)}{1.013D2_t} - \underset{(-9.51)}{.7877(SP_t - SFP_{t-1})}$$

$$S = 1.00 \quad R^2 = .964 \quad \rho = \underset{(0.71)}{.119} \quad d = 2.02 \qquad (4.33)$$

The general level of feeder price is set by the finished animal price, feeder price changing \$1.15 for every dollar change in steer price. The positive coefficient for the feed-range condition variable indicates that when range conditions are favorable, ranchers keep calves off the market longer and thus raise the price.

An increase in the number of beef cows on farms at the beginning of the year, as well as an increase in their rate of change, decreases the price of feeder cattle through the availability of a greater number of calves for feeding purposes.

Slaughter hog price   The price of U.S. Nos. 1, 2 and 3, 200-220 pound barrows and gilts is estimated by the following equation:

$$HP_t = -7.833 + \underset{(38.1)}{.6149PPW_t} - \underset{(-0.96)}{.3066FMW_t} - \underset{(-1.78)}{.3488D4_t}$$

$$- \underset{(-1.36)}{.2769D3_t} + \underset{(1.03)}{.2007D2_t}$$

$$S = 0.47 \quad R^2 = .981 \quad \rho = \underset{(0.79)}{.015} \quad d = 1.41 \qquad (4.34)$$

For every dollar change in the wholesale price of pork, the farm level price changes 61 cents. The food marketing wage rate variable as mentioned above in relation to the finished steer price equation, includes all influencing factors with a significant trend component.

Broiler price   The farm price of broilers is estimated by the following equation:

$$BRF_t = -1.008 + \underset{(63.2)}{.7102BRP_t} - \underset{(-3.95)}{.8348FMW_t}$$

$$S = 0.12 \quad R^2 = .998 \quad \rho = \underset{(2.20)}{.327} \quad d = 1.99 \qquad (4.35)$$

No significant quarterly effects were detected in the initial least squares estimation of this equation. Hence, the usual configuration of dummy variables is absent in the final specification.

CHAPTER V. ECONOMIC SIMULATION

Model Validation

The system of equations specified and estimated in the previous chapter is recursive except for the three wholesale level demand equations which form a simultaneous subset, and the broiler grower price equation which is dependent only upon exogenous variables. To estimate unique values of all endogenous variables for any number of consecutive time periods, it is now only necessary to have a set of initial estimates for the predetermined endogenous variables and estimates for all exogenous variables for the period under study. The current estimates of the endogenous variables become the predetermined variables in later calculations.[1]

For any given year the January 1 cattle inventory equations are first calculated. Quarterly slaughter of the three classes of cattle are derived next, followed by the estimation of average weight per head, total cattle numbers, dressing yield and finally total beef production.

Within the hog sector the quarterly estimates of barrows and gilts and sows slaughtered are followed by the calculations of total hog numbers, average weight per head and total pork production. The estimate of sows farrowing may be made at any point within a given

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[1]The computational task was minimized through the use of the IBM system/360-50 electronic computer. A copy of the computer program may be obtained from the author.

time period since it is not a function of any current endogenous variables.

Broiler grower price may be calculated for all time periods prior to the estimation of any other variables since it is a function only of exogenous variables. In this study it is estimated period by period along with all other variables endogenous to the system. Once broiler production has been estimated, the next step in the sequential chain is to determine the cold storage holdings of the three classes of meat and the current net imports of beef.

The total per capita consumption of each class of meat is now predetermined. On the basis of these pre-assigned consumption levels and several other variables, the wholesale prices of beef, pork and broilers are simultaneously derived. These prices are then extended to the corresponding live animal market.

The calculations of the farm level prices complete the estimates of the endogenous variables for one period. If this period is other than the fourth quarter, then the next step is to again calculate quarterly cattle slaughter. If the converse holds, then the annual cattle inventories are first computed, followed by the quarterly derivations.

The model was initially verified through its ability to reproduce the time paths of the endogenous variables from the second quarter of 1953 through the fourth quarter of 1964, the period on which most of the structural coefficient estimates were based. Historical values were used as the initial conditions for all variables generated prior to the second quarter of 1953 and for the exogenous variables for the period of simulation.

As previously detailed, data for quarterly broiler production are not available prior to the fourth quarter of 1955. The initial values necessary to "start" the simulator were estimated from total poultry production on the basis of the 1956 and 1957 quarterly relationships between broiler and total poultry production, recognizing that the percentage of broilers increased rapidly during this period.

In general only those coefficients estimated by the several regression techniques were used in the simulator model. Any nonlinearities or discontinuities in the relationships were removed through the use of dummy variables in the initial estimation of structural coefficients. It was considered methodologically unsound to adjust coefficients to obtain a more accurate simulation of the historical period if such conclusions could not be derived by regression analysis applied to the original data. That is, the errors from fitting a given equation and the errors due to using calculated independent variables which themselves are not equal to their historical values may be compounded in such a way that one can readily specify an economic hypothesis to justify the changing of one or more coefficients so that the total error is reduced. Such a procedure would not only be one of adjusting the theory to fit the data, but also a case of formulating the theory to correspond to the endogenous data generated by the interactions of a particular structure of random errors.

The only nonregression derived coefficients admitted in the model were the constant terms for the broiler demand and broiler production equations for the initial period of historical simulation. All equations related to the broiler sector were estimated from 1956 through 1964 data. The rapid expansion of the broiler industry in the early 1950's was assumed to be associated with a shifting of the general level of these two equations from that estimated by the regression analysis over the later period. The distorted demand conditions associated with the Korean Conflict conceivably caused a similar shifting of the broiler demand equation as was estimated for beef and pork demands. Hence, the intercept term for the wholesale broiler price equation was set at 9.24 for all quarters up to and including the second quarter of 1956; thereafter the regression estimate of 7.059 was used. Similarly, the constant term for the broiler production equation was assumed to be -800 through the third quarter of 1956 and the regression value of -677 for later quarters.

One further restriction was placed on the model. The estimates of per capita beef, pork and broiler cold storage holdings were not allowed to fall below levels similar to the historical minimum inventories. It was felt that certain minimal stocks would be on hand regardless of that predicted by the economic model. These minimum levels for beef, pork and broilers are, respectively, .600, .750 and .090 pounds per capita. In the simulation of the historical period, these restrictions influenced the estimates of the beef and pork inventories each three times.

Examination of the predicted and actual time paths of the endogenous variables led to several changes in the specification of the model. For example, steers and heifers were originally treated as an aggregate in both the estimation of slaughter and January 1 inventories. The random errors due to the regression fitting of these two equations were sufficiently large in certain time periods that poor simulated estimates of the associated variables were realized. These errors in turn caused larger than tolerable errors in some other variables estimated later in the sequential chain. When steers and heifers are separated into two distinct classes, the individual equations are specified to reflect the different possible alternatives for the disposition of each type of animal. This re-specification and re-estimation resulted in the sum of the standard errors for the separate equations being smaller than that for the corresponding single equation schemes.

The major emphasis was placed on specifying the model to achieve a satisfactory simulation of certain key variables. While errors in the estimation of any variable in the model are likely to have repercussions on the predictive ability of the entire system, a given percentage error[1] in some is not as important as in others. For example, a 10 percent error in the estimate of beef production is about two pounds per capita. A similar percentage error in the

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[1]The percentage error is the actual minus predicted value as a percent of the actual value.

derivation of beef cold storage holdings involves only one-tenth of a pound per capita.

The actual and predicted values for the 35 endogenous variables in the system are given in Table 5.1 and Figure 5.1. In addition, the time paths for certain key variables are graphically displayed in Figures 5.2 to 5.23.

The predicted and actual values of January 1 cattle inventories are shown in Figures 5.2 to 5.5. The most serious shortcoming in these four relationships is the large difference between actual and predicted beef cow numbers at the peak of their cycle (Figure 5.2). This error can principally be attributed to the persistent under-estimation of feeder calf prices from the first quarter of 1954 through the fourth quarter of 1958.

The model's simulation or reproduction of wholesale beef prices (Figure 5.6) is perhaps the weakest feature of the entire model. Several different specifications of this equation were estimated in an attempt to achieve a more satisfactory simulation. For example, rather than assuming that the own price elasticity of demand varies by season, a seasonal intercept shift was allowed. The autoregressive least squares estimation of this specification yielded a price elasticity of demand for beef of -.49 based on 1955-1957 averages for price and quantity. The equation was re-estimated with the coefficient estimate for per capita beef consumption constrained such that the afore described elasticity was -.76. The coefficient estimates of those variables common to each of the four alternative

Table 5.1 Actual and predicted values of annual endogenous variables in livestock-meat economy, United States, 1954 to 1964

Year	CBS		CVS		STS		HES		SHS	
	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1954	25,050	24,477	17,978	18,256	8,229	8,476	6,365	6,534	14,594	15,010
1955	25,659	24,680	18,804	18,812	8,444	8,572	6,514	6,371	14,958	14,943
1956	25,371	24,535	18,869	18,766	9,483	8,881	6,206	6,310	15,689	15,191
1957	24,534	24,283	18,405	18,468	8,991	8,924	5,926	6,266	14,917	15,190
1958	24,165	24,184	18,275	18,770	9,252	9,147	5,903	6,238	15,155	15,385
1959	25,112	24,838	19,407	19,466	9,931	10,267	6,557	6,740	16,488	17,007
1960	26,344	26,131	20,425	19,974	10,574	10,789	7,036	7,221	17,610	18,010
1961	27,102	27,481	20,705	20,891	10,977	10,778	7,069	7,310	18,046	18,088
1962	28,305	28,748	22,050	21,987	11,060	11,065	7,333	7,519	18,393	18,584
1963	29,970	30,042	23,330	23,128	12,129	11,539	7,909	7,885	20,038	19,424
1964	31,811	31,442	24,575	24,219	12,574	12,035	8,326	8,378	20,900	20,413

YEAR AND QUARTER		BSN ACTUAL	BSN PREDICTED	PSN ACTUAL	PSN PREDICTED	BRSN ACTUAL	BRSN PREDICTED
1953	2	1.247	1.295	2.946	2.938	0.102	0.106
	3	0.900	1.096	1.697	1.589	0.089	0.117
	4	1.253	1.196	1.690	1.503	0.119	0.144
1954	1	1.296	1.212	2.611	2.560	0.150	0.149
	2	0.801	0.808	2.417	2.424	0.132	0.114
	3	0.709	0.767	1.431	1.527	0.113	0.127
	4	0.985	1.019	2.122	2.043	0.146	0.153
1955	1	0.956	1.046	3.295	3.141	0.117	0.145
	2	0.735	0.709	2.940	2.928	0.057	0.099
	3	0.677	0.710	1.340	1.761	0.068	0.102
	4	0.977	0.967	1.871	2.009	0.124	0.127
1956	1	1.192	0.951	3.145	2.820	0.144	0.121
	2	0.938	0.647	2.765	2.689	0.119	0.098
	3	0.720	0.606	1.225	1.605	0.113	0.118
	4	1.209	0.846	1.488	1.909	0.142	0.151
1957	1	1.217	0.847	1.984	2.280	0.118	0.131
	2	0.774	0.610	1.912	2.005	0.103	0.100
	3	0.661	0.600	0.869	0.750	0.090	0.105
	4	0.769	0.809	0.962	0.750	0.123	0.133
1958	1	0.679	0.778	1.333	1.338	0.095	0.123
	2	0.583	0.600	1.415	1.497	0.092	0.111
	3	0.682	0.600	0.864	0.750	0.107	0.127
	4	0.915	0.856	1.063	0.992	0.177	0.157
1959	1	0.995	0.902	1.817	1.672	0.178	0.137
	2	0.992	0.883	2.092	1.939	0.141	0.116
	3	0.928	0.841	1.047	1.016	0.149	0.121
	4	1.006	1.072	1.270	1.224	0.152	0.143
1960	1	1.049	1.083	1.936	1.805	0.117	0.121
	2	0.835	0.975	2.175	1.990	0.099	0.105
	3	0.859	0.891	1.238	0.932	0.114	0.113
	4	0.943	1.095	0.857	1.065	0.135	0.139
1961	1	0.800	1.085	1.306	1.600	0.108	0.120
	2	0.850	0.919	1.487	1.850	0.110	0.108
	3	0.922	0.850	0.755	0.854	0.168	0.115
	4	1.107	1.072	1.060	0.993	0.182	0.141
1962	1	0.928	1.043	1.290	1.517	0.102	0.123
	2	0.771	0.953	1.848	1.895	0.105	0.114
	3	0.747	0.924	0.988	0.986	0.115	0.120
	4	0.923	1.132	1.146	1.114	0.132	0.143
1963	1	0.955	1.055	1.485	1.576	0.137	0.121
	2	0.995	0.977	1.914	1.992	0.110	0.114
	3	1.079	0.976	1.179	1.122	0.111	0.121
	4	1.431	1.178	1.336	1.273	0.141	0.145
1964	1	1.426	1.089	2.031	1.712	0.149	0.120
	2	1.442	1.028	2.483	2.070	0.123	0.110
	3	1.524	1.047	1.209	1.136	0.123	0.114
	4	1.531	1.257	1.446	1.185	0.125	0.138

FIGURE 5.1 ACTUAL AND PREDICTED VALUES OF QUARTERLY ENDOGENOUS VARIABLES IN LIVESTOCK-MEAT ECONOMY, UNITED STATES, SECOND QUARTER 1953 TO FOURTH QUARTER 1964

YEAR AND QUARTER		BCN ACTUAL	BCN PREDICTED	PCN ACTUAL	PCN PREDICTED	BRCN ACTUAL	BRCN PREDICTED
1953	2	18.27	18.56	14.29	13.70	*	5.47
	3	19.32	19.89	12.57	12.54	*	6.78
	4	19.88	20.34	14.44	13.83	*	5.49
1954	1	18.71	19.42	13.37	15.00	*	5.16
	2	19.46	19.78	12.78	13.45	*	6.37
	3	19.94	20.98	12.56	13.40	*	7.87
	4	19.41	20.97	14.58	15.40	*	6.04
1955	1	18.47	20.04	15.45	16.76	*	5.46
	2	19.29	20.19	14.49	14.92	*	6.19
	3	20.75	21.49	13.58	14.56	*	7.37
	4	20.84	21.57	16.42	15.96	*	5.46
1956	1	20.13	20.57	17.36	16.03	4.99	4.99
	2	20.62	20.54	15.48	14.69	6.02	6.09
	3	21.30	21.17	14.04	14.12	7.39	7.58
	4	20.66	20.95	15.78	15.59	6.95	6.15
1957	1	20.55	20.00	14.52	15.67	5.83	5.57
	2	20.31	20.10	14.03	14.38	6.51	6.83
	3	20.70	20.88	12.74	12.89	7.70	8.21
	4	20.44	20.35	14.68	14.48	7.43	6.96
1958	1	19.37	19.33	13.93	14.24	6.48	6.58
	2	18.50	19.40	13.23	13.54	7.61	7.88
	3	20.01	19.87	12.76	12.69	9.19	9.13
	4	19.86	19.32	14.70	15.02	7.93	7.77
1959	1	18.97	18.57	15.32	15.15	7.38	7.25
	2	19.02	19.60	14.77	14.87	8.71	8.45
	3	20.39	20.66	14.87	14.22	9.29	9.41
	4	20.43	20.30	16.63	16.12	7.73	7.84
1960	1	20.05	19.71	16.80	16.04	6.94	7.30
	2	20.16	20.59	15.26	15.51	8.69	8.51
	3	21.65	21.72	14.38	14.37	9.64	9.54
	4	21.24	21.37	15.17	15.99	8.16	8.17
1961	1	19.73	20.82	14.50	15.53	7.92	7.65
	2	21.03	21.17	14.71	15.17	9.91	8.80
	3	22.76	22.41	13.88	13.74	11.06	9.95
	4	21.84	21.87	15.18	15.36	8.87	8.74
1962	1	20.78	21.16	15.12	15.19	7.78	8.28
	2	21.43	21.87	15.14	15.08	9.73	9.46
	3	22.76	23.09	14.36	13.71	10.65	10.47
	4	21.81	22.63	15.51	15.48	9.01	9.27
1963	1	21.11	21.68	15.50	15.22	8.92	8.72
	2	22.75	22.46	15.84	15.29	9.59	9.89
	3	23.68	23.81	14.03	14.04	11.30	10.85
	4	23.69	23.21	16.30	15.83	9.21	9.61
1964	1	23.15	22.30	16.16	15.26	9.16	9.10
	2	24.19	23.23	15.38	15.32	10.04	10.33
	3	25.27	24.70	14.35	13.76	10.96	11.32
	4	24.76	24.33	16.27	15.43	9.51	10.25

FIGURE 5.1 (CONTINUED)

* DATA NOT AVAILABLE.

YEAR AND QUARTER		BPW ACTUAL	BPW PREDICTED	PPW ACTUAL	PPW PREDICTED	BRP ACTUAL	BRP PREDICTED
1953	2	37.00	38.35	50.53	52.70	40.90	41.21
	3	39.46	37.71	56.54	56.49	42.07	40.18
	4	41.23	37.38	49.74	53.26	41.93	38.07
1954	1	39.07	38.93	54.34	47.67	37.80	37.49
	2	39.13	38.02	56.67	50.87	37.97	38.75
	3	39.21	38.20	52.33	49.09	39.70	36.65
	4	41.71	37.64	44.59	44.01	34.83	35.21
1955	1	43.45	38.30	42.24	40.64	[illegible]	34.13
	2	39.26	36.11	41.57	43.45	44.57	35.84
	3	37.58	35.91	44.88	42.23	42.23	34.46
	4	37.83	35.29	38.75	38.66	36.03	34.00
1956	1	34.84	34.57	33.93	36.80	33.60	34.49
	2	33.61	34.91	37.38	39.03	34.33	36.74
	3	38.64	37.93	41.45	41.37	33.00	33.36
	4	43.67	38.95	39.42	40.98	29.10	30.33
1957	1	36.00	38.95	42.09	39.10	29.40	31.00
	2	37.46	39.92	43.55	43.81	31.20	31.97
	3	41.00	41.52	49.10	49.17	33.70	31.78
	4	41.13	42.94	44.33	45.90	28.47	29.73
1958	1	44.22	43.18	47.01	46.34	30.97	30.28
	2	46.89	44.36	50.79	49.48	33.00	30.64
	3	44.44	45.05	52.73	51.27	31.60	30.13
	4	43.90	46.29	46.98	45.08	26.80	27.88
1959	1	46.06	45.34	42.99	42.60	27.73	28.76
	2	46.82	42.16	40.98	41.90	27.90	28.48
	3	45.42	42.14	40.32	44.11	26.93	27.85
	4	43.97	44.46	37.79	40.63	25.77	26.45
1960	1	44.29	43.75	36.13	38.78	29.17	27.90
	2	45.99	41.99	40.86	39.29	29.67	27.97
	3	43.45	41.65	43.18	42.02	29.00	27.92
	4	42.42	43.63	43.07	40.15	26.77	25.97
1961	1	45.09	43.46	43.33	41.05	27.80	27.05
	2	41.65	42.61	41.84	40.44	26.03	27.64
	3	38.57	41.93	42.46	44.19	22.40	27.77
	4	40.49	43.81	42.73	42.57	21.80	25.62
1962	1	43.64	42.86	41.89	41.63	27.60	26.61
	2	43.62	41.86	40.70	41.47	26.13	26.49
	3	43.25	42.06	44.10	45.05	25.77	26.81
	4	47.42	43.99	44.06	43.10	26.20	24.38
1963	1	44.92	42.96	40.90	41.77	25.83	25.83
	2	40.19	41.44	37.43	39.33	26.13	25.63
	3	41.65	42.08	43.55	44.19	25.07	25.97
	4	40.79	43.76	40.55	41.14	24.97	24.01
1964	1	38.82	42.52	39.11	41.89	24.40	25.69
	2	37.41	40.06	38.21	39.80	24.43	25.41
	3	39.61	40.25	42.01	44.67	25.33	26.09
	4	41.57	41.29	40.77	42.10	25.37	23.51

FIGURE 5.1 (CONTINUED)

YEAR AND QUARTER		SP ACTUAL	SP PREDICTED	SFP ACTUAL	SFP PREDICTED	HP ACTUAL	HP PREDICTED
1953	2	23.68	23.79	22.89	23.36	22.63	24.16
	3	23.91	22.92	18.60	20.66	25.53	26.01
	4	25.51	22.75	17.90	18.96	22.56	23.93
1954	1	24.32	23.46	20.03	18.76	25.59	20.84
	2	24.32	23.39	20.67	19.72	27.12	23.01
	3	23.98	23.13	19.05	18.57	23.89	21.44
	4	25.41	22.85	20.72	17.77	19.40	18.23
1955	1	26.56	23.00	21.01	18.13	17.74	16.51
	2	24.50	22.07	22.08	18.92	17.41	18.44
	3	22.59	21.55	21.04	18.53	18.26	17.21
	4	21.84	21.21	20.41	18.79	14.52	14.93
1956	1	19.75	20.40	19.49	18.76	12.18	14.12
	2	20.22	21.16	19.65	19.82	15.23	15.70
	3	23.08	22.81	19.43	19.17	16.96	16.66
	4	25.88	23.60	19.67	18.83	15.84	16.33
1957	1	21.26	23.25	19.67	18.82	17.64	15.51
	2	22.72	24.45	22.15	21.38	18.23	18.61
	3	24.74	25.14	23.75	23.02	20.96	21.43
	4	24.95	26.18	25.45	25.15	18.20	19.33
1958	1	26.78	26.00	27.73	27.15	19.83	19.93
	2	29.37	27.34	31.22	30.37	21.93	22.07
	3	27.06	27.44	31.55	30.83	22.88	22.70
	4	26.71	28.36	33.73	32.02	19.60	18.80
1959	1	27.72	27.38	33.94	32.13	17.42	17.62
	2	29.59	25.77	35.14	32.32	16.70	17.39
	3	27.98	25.38	33.55	30.62	15.48	18.27
	4	27.11	27.03	30.38	30.58	13.35	16.04
1960	1	26.23	26.21	27.31	29.77	13.15	15.24
	2	27.76	25.55	29.99	29.92	16.35	15.76
	3	25.58	24.94	27.31	28.27	17.64	16.96
	4	25.27	26.38	26.37	27.87	17.54	15.72
1961	1	26.82	25.93	27.39	27.53	18.26	16.62
	2	24.73	25.90	28.26	28.28	17.60	16.44
	3	22.99	25.06	27.42	26.74	18.10	18.27
	4	24.82	26.43	27.86	26.60	17.43	17.20
1962	1	26.43	25.45	26.69	26.25	17.35	16.95
	2	26.93	25.31	27.30	27.03	16.49	17.05
	3	26.65	25.08	27.48	26.23	18.48	18.78
	4	29.83	26.48	28.91	26.51	17.85	17.50
1963	1	27.04	25.43	28.34	26.30	16.29	17.02
	2	23.34	24.94	27.73	26.79	14.76	15.72
	3	24.00	25.00	27.70	25.44	18.16	18.23
	4	23.83	26.22	25.78	25.31	15.72	16.27
1964	1	22.08	25.04	24.43	24.77	15.28	17.06
	2	21.12	23.91	23.74	24.89	15.28	15.98
	3	23.43	23.67	21.93	23.16	17.42	18.50
	4	25.26	24.45	21.31	22.64	16.21	16.83

FIGURE 5.1 (CONTINUED)

YEAR AND QUARTER		BRF ACTUAL	BRF PREDICTED	HEQ ACTUAL	HEQ PREDICTED	STQ ACTUAL	STQ PREDICTED
1953	2	27.77	26.56	574.	652.	3389.	3237.
	3	27.47	25.71	643.	682.	3383.	3422.
	4	26.60	24.15	792.	829.	2980.	3134.
1954	1	23.33	23.71	883.	791.	2982.	3137.
	2	23.83	24.60	734.	764.	3323.	3276.
	3	24.90	23.10	805.	843.	3350.	3411.
	4	21.37	22.07	914.	969.	2975.	3140.
1955	1	23.00	21.30	913.	881.	2819.	3177.
	2	28.37	22.51	952.	813.	3153.	3397.
	3	26.87	21.52	869.	917.	3354.	3511.
	4	22.80	21.17	872.	1041.	3202.	3247.
1956	1	20.47	21.50	948.	982.	3286.	3278.
	2	21.27	23.07	915.	921.	3692.	3485.
	3	20.40	20.67	914.	931.	3613.	3560.
	4	17.40	18.51	978.	1072.	3112.	3202.
1957	1	18.03	18.94	1069.	1091.	3327.	3142.
	2	19.20	19.62	958.	1044.	3514.	3324.
	3	20.93	19.48	987.	1028.	3436.	3461.
	4	17.33	18.00	1037.	1100.	3229.	3148.
1958	1	18.90	18.36	949.	1041.	3138.	3107.
	2	20.37	18.60	970.	1036.	3118.	3315.
	3	19.33	18.24	981.	1068.	3497.	3344.
	4	15.97	16.62	1029.	1179.	3289.	3019.
1959	1	16.30	17.22	972.	1115.	3085.	2983.
	2	16.33	17.00	1153.	1211.	3129.	3392.
	3	15.83	16.56	1203.	1180.	3327.	3586.
	4	15.03	15.54	1395.	1287.	3225.	3284.
1960	1	17.37	16.54	1263.	1238.	3263.	3217.
	2	17.63	16.57	1217.	1294.	3470.	3573.
	3	17.30	16.53	1344.	1297.	3668.	3763.
	4	15.77	15.13	1494.	1446.	3409.	3418.
1961	1	16.50	15.89	1392.	1405.	3155.	3356.
	2	15.17	16.29	1443.	1355.	3612.	3659.
	3	12.63	16.38	1406.	1403.	3932.	3813.
	4	12.00	14.84	1568.	1561.	3529.	3471.
1962	1	16.07	15.51	1363.	1451.	3515.	3411.
	2	15.03	15.41	1286.	1436.	3816.	3808.
	3	14.90	15.65	1418.	1493.	3974.	3934.
	4	15.13	13.90	1639.	1648.	3381.	3581.
1963	1	15.03	14.90	1369.	1476.	3537.	3584.
	2	15.27	14.74	1476.	1479.	4026.	3994.
	3	14.47	14.99	1468.	1532.	4111.	4151.
	4	14.20	13.58	1647.	1686.	3911.	3738.
1964	1	13.90	14.73	1501.	1520.	3928.	3756.
	2	13.90	14.51	1490.	1536.	4528.	4248.
	3	14.50	15.00	1537.	1585.	4748.	4431.
	4	14.53	13.15	1726.	1743.	4231.	4068.

FIGURE 5.1 (CONTINUED)

YEAR AND QUARTER		SHQ ACTUAL	SHQ PREDICTED	COQ ACTUAL	COQ PREDICTED	HQ ACTUAL	HQ PREDICTED
1953	2	3963.	3889.	1249.	1587.	14986.	14475.
	3	4027.	4104.	1744.	1817.	9412.	9325.
	4	3772.	3963.	2759.	2277.	16556.	15643.
1954	1	3865.	3929.	2021.	2139.	16419.	18269.
	2	4056.	4040.	1727.	1918.	13134.	14891.
	3	4155.	4254.	2147.	2275.	9397.	10914.
	4	3889.	4109.	2578.	2624.	17621.	18350.
1955	1	3732.	4058.	2147.	2179.	18923.	20179.
	2	4106.	4210.	1925.	1937.	15567.	16669.
	3	4223.	4429.	2315.	2341.	10405.	12680.
	4	4075.	4288.	2622.	2654.	19762.	19192.
1956	1	4234.	4260.	2015.	2092.	22222.	20020.
	2	4607.	4406.	1636.	1864.	17778.	17004.
	3	4527.	4491.	2195.	2236.	12376.	12944.
	4	4089.	4274.	2931.	2550.	19564.	18768.
1957	1	4396.	4234.	2150.	2016.	18310.	18971.
	2	4472.	4368.	1733.	1789.	16593.	16595.
	3	4423.	4489.	2169.	2088.	12013.	11950.
	4	4267.	4248.	2273.	2303.	18347.	17342.
1958	1	4086.	4148.	1764.	1701.	17498.	17691.
	2	4088.	4351.	1480.	1411.	15505.	16202.
	3	4478.	4411.	1455.	1491.	13054.	12256.
	4	4317.	4197.	1584.	1715.	17736.	18076.
1959	1	4057.	4097.	1290.	1344.	19271.	18910.
	2	4282.	4603.	1129.	1109.	17667.	17973.
	3	4530.	4766.	1234.	1158.	15183.	14017.
	4	4620.	4571.	1350.	1515.	20279.	19670.
1960	1	4526.	4455.	1313.	1305.	21496.	20216.
	2	4688.	4866.	1250.	1088.	18873.	19011.
	3	5012.	5060.	1486.	1233.	15230.	14422.
	4	4902.	4863.	1678.	1620.	17763.	19656.
1961	1	4547.	4761.	1375.	1370.	18235.	19805.
	2	5055.	5014.	1157.	1125.	18271.	18820.
	3	5338.	5217.	1246.	1367.	14820.	14174.
	4	5097.	5032.	1499.	1762.	19079.	19114.
1962	1	4878.	4862.	1258.	1394.	18710.	19283.
	2	5102.	5244.	1154.	1139.	19026.	18910.
	3	5392.	5427.	1368.	1466.	15288.	14322.
	4	5020.	5229.	1657.	1846.	19031.	19258.
1963	1	4906.	5059.	1286.	1358.	19548.	19384.
	2	5502.	5473.	1101.	1086.	20298.	19316.
	3	5579.	5682.	1261.	1479.	15217.	14873.
	4	5559.	5424.	1529.	1895.	20255.	19594.
1964	1	5429.	5276.	1379.	1349.	20916.	19702.
	2	6017.	5784.	1247.	1075.	19732.	19403.
	3	6285.	6016.	1576.	1572.	15184.	14706.
	4	5957.	5811.	2108.	2028.	20052.	19040.

FIGURE 5.1 (CONTINUED)

YEAR AND QUARTER		SQ ACTUAL	SQ PREDICTED	CAAW ACTUAL	CAAW PREDICTED	ZAW ACTUAL	ZAW PREDICTED
1953	2	1148.	952.	957.	945.	232.3	234.4
	3	3301.	3501.	923.	934.	247.3	248.9
	4	1210.	1312.	916.	941.	226.3	230.7
1954	1	731.	1310.	947.	955.	236.0	235.6
	2	1356.	1285.	936.	939.	243.3	235.8
	3	3634.	3656.	908.	923.	252.3	246.9
	4	1279.	1564.	913.	932.	231.3	230.6
1955	1	957.	1645.	946.	958.	239.3	235.5
	2	1578.	1588.	935.	946.	240.3	235.5
	3	3681.	3444.	927.	931.	247.0	242.3
	4	1659.	1500.	946.	944.	229.0	227.9
1956	1	1458.	1395.	979.	973.	233.3	231.7
	2	1771.	1441.	969.	956.	231.7	232.8
	3	3274.	3139.	941.	935.	238.7	240.7
	4	1539.	1646.	939.	944.	227.3	230.7
1957	1	1275.	1376.	972.	976.	232.7	235.3
	2	1552.	1313.	962.	966.	236.0	234.9
	3	3015.	2685.	937.	948.	238.3	240.8
	4	1345.	1305.	957.	958.	226.0	230.7
1958	1	1152.	1134.	989.	993.	232.0	235.2
	2	1421.	1196.	977.	983.	236.0	235.4
	3	2350.	2632.	972.	966.	239.3	242.1
	4	1549.	1498.	994.	976.	233.0	233.0
1959	1	1374.	1263.	1035.	1005.	236.7	236.1
	2	1658.	1428.	1021.	998.	238.7	236.6
	3	2634.	2810.	1003.	983.	239.3	241.1
	4	1881.	1724.	1004.	989.	233.7	232.3
1960	1	1487.	1327.	1027.	1016.	233.3	235.8
	2	1471.	1454.	1010.	1009.	235.0	236.4
	3	2169.	2625.	987.	990.	240.0	240.2
	4	1634.	1653.	997.	994.	235.7	232.1
1961	1	1285.	1238.	1024.	1023.	237.3	236.2
	2	1316.	1346.	1021.	1018.	238.3	237.4
	3	2354.	2341.	1012.	996.	242.0	239.9
	4	1648.	1557.	1008.	996.	234.0	233.0
1962	1	1340.	1213.	1024.	1029.	238.3	238.3
	2	1377.	1318.	1016.	1026.	238.7	238.6
	3	2194.	2296.	996.	1001.	242.7	241.3
	4	1592.	1557.	989.	1000.	237.3	234.3
1963	1	1268.	1235.	1028.	1034.	238.3	239.7
	2	1342.	1399.	1031.	1033.	236.3	240.9
	3	2268.	2354.	1020.	1003.	240.7	242.9
	4	1672.	1743.	1015.	1001.	236.7	237.7
1964	1	1501.	1303.	1044.	1040.	240.3	241.9
	2	1326.	1362.	1043.	1041.	239.7	242.4
	3	2080.	2164.	1006.	1010.	243.7	243.9
	4	1671.	1662.	997.	1005.	240.0	238.2

FIGURE 5.1 (CONTINUED)

YEAR AND QUARTER	CY ACTUAL	CY PREDICTED	BQ ACTUAL	BQ PREDICTED	PQ ACTUAL	PQ PREDICTED
1953 2	56.5	55.7	2881.	2937.	2142.	2047.
3	55.6	55.6	3040.	3141.	1823.	1801.
4	53.3	54.5	3266.	3261.	2345.	2235.
1954 1	54.7	54.6	3090.	3222.	2338.	2615.
2	55.8	55.5	3063.	3160.	2047.	2161.
3	55.2	55.2	3224.	3398.	1886.	2032.
4	54.0	54.3	3243.	3471.	2522.	2624.
1955 1	54.6	54.9	3071.	3333.	2722.	2922.
2	55.6	55.8	3172.	3298.	2356.	2445.
3	55.4	55.4	3416.	3564.	1987.	2214.
4	54.6	54.6	3514.	3638.	2829.	2706.
1956 1	55.6	55.4	3432.	3468.	3125.	2834.
2	56.6	56.2	3447.	3416.	2543.	2455.
3	55.7	55.8	3572.	3572.	2122.	2210.
4	53.9	54.9	3610.	3592.	2745.	2722.
1957 1	55.3	55.7	3551.	3435.	2585.	2757.
2	56.3	56.5	3387.	3399.	2402.	2425.
3	55.8	56.2	3502.	3559.	2044.	2032.
4	55.1	55.4	3491.	3521.	2560.	2510.
1958 1	55.5	56.2	3235.	3293.	2482.	2571.
2	56.0	57.2	3070.	3264.	2315.	2380.
3	56.9	57.2	3305.	3296.	2142.	2096.
4	56.7	56.4	3346.	3283.	2612.	2674.
1959 1	57.1	56.9	3164.	3127.	2821.	2777.
2	57.8	57.8	3199.	3313.	2661.	2675.
3	57.8	57.9	3358.	3397.	2459.	2365.
4	57.4	57.1	3443.	3453.	3014.	2920.
1960 1	57.4	57.2	3445.	3357.	3123.	2972.
2	57.7	58.0	3469.	3496.	2796.	2831.
3	57.6	58.0	3720.	3636.	2426.	2402.
4	56.9	57.1	3751.	3699.	2686.	2923.
1961 1	57.1	57.3	3470.	3601.	2727.	2927.
2	58.2	58.1	3700.	3637.	2726.	2821.
3	58.4	57.9	3900.	3819.	2419.	2345.
4	57.7	57.1	3840.	3877.	2865.	2868.
1962 1	57.5	57.4	3607.	3697.	2831.	2898.
2	58.0	58.2	3685.	3812.	2906.	2861.
3	57.8	57.9	3902.	4017.	2518.	2390.
4	56.9	57.1	3760.	4053.	2931.	2920.
1963 1	57.5	57.6	3663.	3818.	2978.	2949.
2	58.6	58.4	3984.	3951.	3079.	2972.
3	58.5	58.0	4078.	4185.	2530.	2506.
4	57.8	57.2	4154.	4200.	3139.	3049.
1964 1	58.1	57.7	4129.	3970.	3265.	3046.
2	58.6	58.5	4440.	4168.	3046.	3014.
3	58.1	58.1	4611.	4467.	2535.	2485.
4	57.1	57.2	4613.	4522.	3185.	2989.

FIGURE 5.1 (CONTINUED)

YEAR AND QUARTER		CAQ ACTUAL	CAQ PREDICTED	ZAQ ACTUAL	ZAQ PREDICTED	BRGP ACTUAL	BRGP PREDICTED
1953	2	5389.	5640.	16231.	15507.	5.32	5.34
	3	5982.	6105.	12833.	12939.	5.24	5.26
	4	6736.	6417.	17822.	17030.	5.15	5.21
1954	1	6020.	6225.	17213.	19673.	5.24	5.25
	2	5933.	6130.	14578.	16273.	5.41	5.25
	3	6492.	6727.	13118.	14698.	5.38	5.26
	4	6631.	6918.	18961.	20003.	5.23	5.23
1955	1	5995.	6388.	19980.	21927.	5.18	5.22
	2	6166.	6312.	17261.	18364.	5.12	5.15
	3	6710.	6963.	14227.	16258.	5.00	5.05
	4	6854.	7120.	21484.	20783.	4.83	4.88
1956	1	6362.	6491.	23806.	21517.	4.79	4.89
	2	6360.	6423.	19639.	18552.	4.91	5.02
	3	6883.	6907.	15765.	16217.	5.08	5.12
	4	7180.	6990.	21180.	20505.	4.98	5.06
1957	1	6662.	6376.	19665.	20445.	4.94	5.00
	2	6328.	6299.	18224.	18013.	4.93	4.95
	3	6766.	6742.	15135.	14764.	4.88	4.91
	4	6678.	6697.	19757.	18731.	4.84	4.82
1958	1	5950.	5953.	18732.	18917.	4.81	4.77
	2	5668.	5878.	17010.	17502.	4.98	4.83
	3	6038.	6030.	15517.	15018.	5.07	4.89
	4	5998.	6022.	19362.	19661.	4.97	4.80
1959	1	5414.	5521.	20693.	20270.	4.95	4.80
	2	5492.	5806.	19416.	19511.	4.91	4.85
	3	5859.	6030.	17912.	16963.	4.85	4.84
	4	6049.	6179.	22248.	21487.	4.72	4.73
1960	1	5902.	5832.	23068.	21645.	4.69	4.73
	2	6023.	6041.	20452.	20579.	4.68	4.77
	3	6609.	6397.	17498.	17185.	4.64	4.74
	4	6674.	6576.	19481.	21403.	4.56	4.65
1961	1	5996.	6199.	19620.	21144.	4.54	4.67
	2	6302.	6222.	19672.	20279.	4.69	4.68
	3	6673.	6688.	17272.	16651.	4.70	4.66
	4	6672.	6888.	20827.	20762.	4.59	4.66
1962	1	6190.	6321.	20138.	20594.	4.64	4.67
	2	6326.	6460.	20533.	20341.	4.66	4.69
	3	6847.	6997.	17693.	16754.	4.65	4.66
	4	6749.	7168.	20757.	20906.	4.70	4.66
1963	1	6251.	6474.	20962.	20718.	4.81	4.75
	2	6668.	6629.	21792.	20830.	4.76	4.79
	3	6907.	7260.	17715.	17366.	4.79	4.85
	4	7150.	7408.	22074.	21430.	4.83	4.83
1964	1	6869.	6677.	22568.	21105.	4.83	4.83
	2	7341.	6924.	21207.	20880.	4.82	4.84
	3	7954.	7687.	17439.	17007.	4.77	4.81
	4	8171.	7931.	21846.	20792.	4.79	4.80

FIGURE 5.1 (CONTINUED)

YEAR AND		BTN		SFQ		BRQ	
QUARTER		ACTUAL	PREDICTED	ACTUAL	PREDICTED	ACTUAL	PREDICTED
1953	2	0.436	0.405	1249.	1587.	*	851.
	3	0.402	0.478	1744.	1817.	*	1065.
	4	0.159	0.397	2759.	2277.	*	869.
1954	1	0.208	0.049	2021.	2139.	*	818.
	2	0.415	0.212	1727.	1918.	*	1008.
	3	0.300	0.294	2147.	2275.	*	1260.
	4	0.156	0.267	2578.	2624.	*	975.
1955	1	0.019	0.034	2147.	2179.	*	880.
	2	0.210	0.199	1925.	1937.	*	997.
	3	0.368	0.261	2315.	2341.	*	1202.
	4	0.317	0.246	2622.	2654.	*	899.
1956	1	0.085	0.057	2539.	2386.	825.	820.
	2	0.157	0.210	5116.	5106.	992.	1003.
	3	0.247	0.288	2641.	2771.	1227.	1263.
	4	0.138	0.281	2540.	2528.	1165.	1033.
1957	1	-0.048	0.090	2387.	2199.	974.	932.
	2	0.326	0.242	4807.	4724.	1094.	1146.
	3	0.402	0.344	2677.	2664.	1302.	1391.
	4	0.529	0.365	2435.	2587.	1270.	1189.
1958	1	0.872	0.557	2680.	2343.	1103.	1123.
	2	1.055	0.732	4601.	4850.	1306.	1351.
	3	1.518	1.331	3141.	2985.	1589.	1579.
	4	1.280	1.125	2746.	2814.	1388.	1353.
1959	1	1.294	1.076	3053.	2568.	1283.	1258.
	2	1.277	1.185	4943.	5000.	1515.	1472.
	3	1.682	1.750	3346.	3187.	1631.	1652.
	4	1.436	1.397	2782.	2809.	1362.	1385.
1960	1	1.074	1.196	2511.	2565.	1222.	1288.
	2	0.918	1.295	4279.	4775.	1541.	1509.
	3	1.352	1.774	3042.	3134.	1721.	1702.
	4	0.860	1.392	2813.	2718.	1466.	1469.
1961	1	0.745	1.235	2529.	2460.	1420.	1373.
	2	1.102	1.373	4500.	4564.	1790.	1588.
	3	1.798	1.756	3099.	3105.	2016.	1806.
	4	1.500	1.369	2854.	2689.	1617.	1596.
1962	1	1.309	1.342	2587.	2480.	1405.	1509.
	2	1.665	1.478	4436.	4500.	1784.	1731.
	3	2.066	1.761	3177.	3133.	1961.	1928.
	4	2.153	1.408	2993.	2735.	1669.	1717.
1963	1	1.881	1.510	2608.	2497.	1656.	1613.
	2	1.897	1.659	4524.	4487.	1780.	1839.
	3	2.396	1.863	3182.	3116.	2108.	2026.
	4	2.370	1.486	2909.	2669.	1732.	1804.
1964	1	1.732	1.640	2389.	2376.	1726.	1708.
	2	1.382	1.785	4240.	4231.	1891.	1949.
	3	1.742	1.861	2960.	3095.	2077.	2146.
	4	1.204	1.441	2670.	2570.	1809.	1955.

FIGURE 5.1 (CONTINUED)

FIGURE 5.2 BEEF COW JANUARY 1 INVENTORY, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

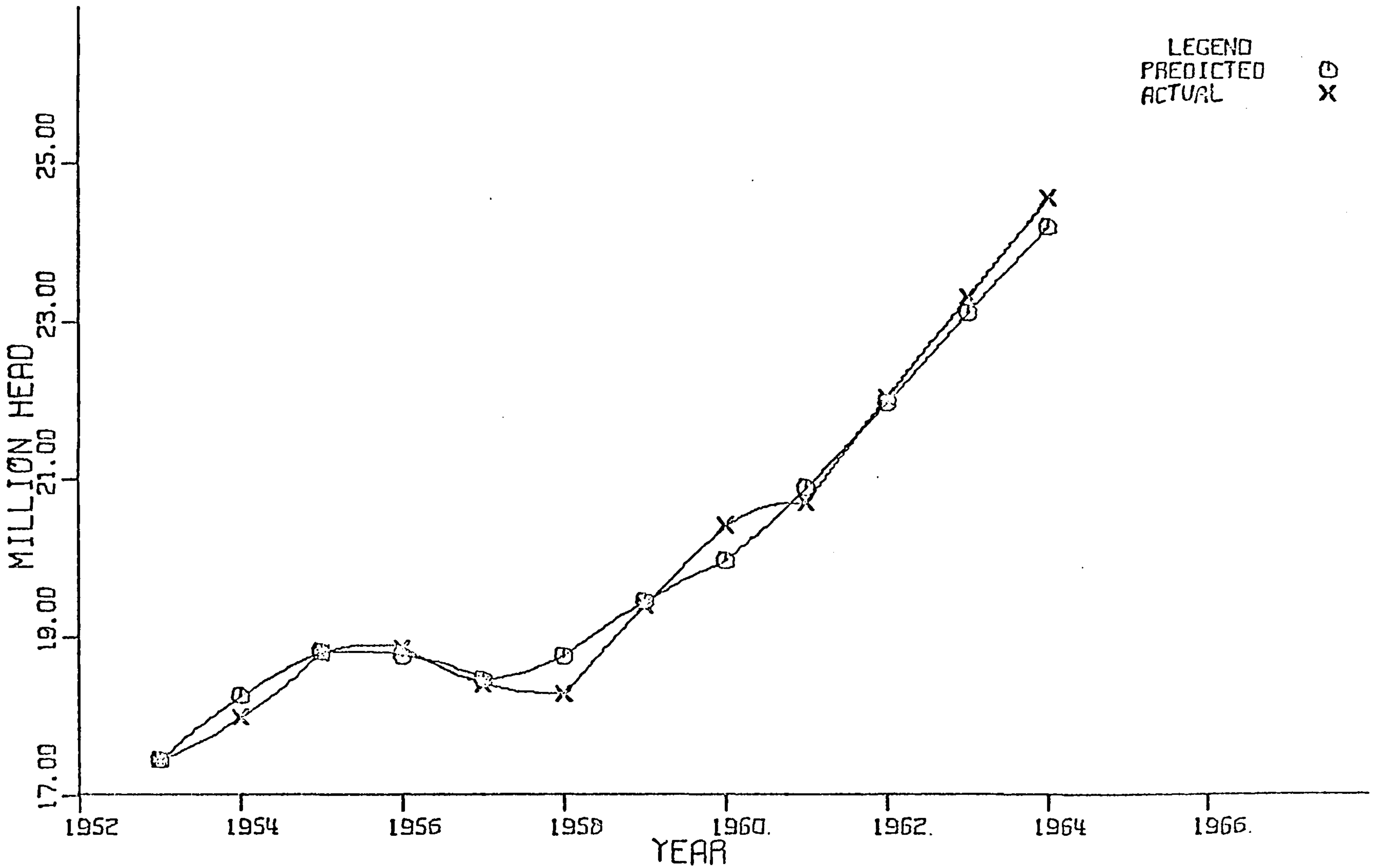

FIGURE 5. 8 BEEF CALVES LESS THAN ONE YEAR OLD JANUARY 1 INVENTORY, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

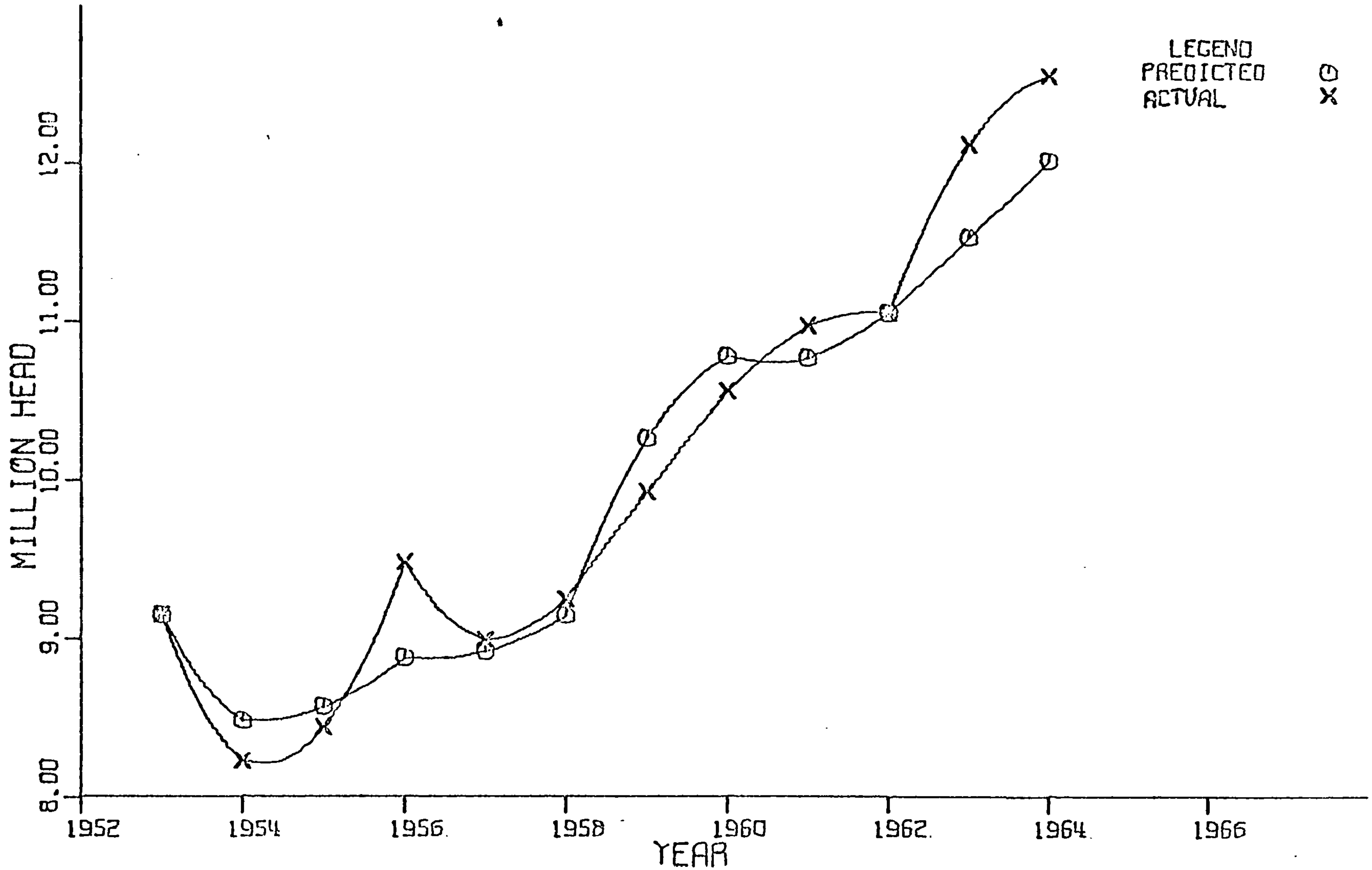

FIGURE 5.4 STEERS ONE YEAR AND OLDER JANUARY 1 INVENTORY, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

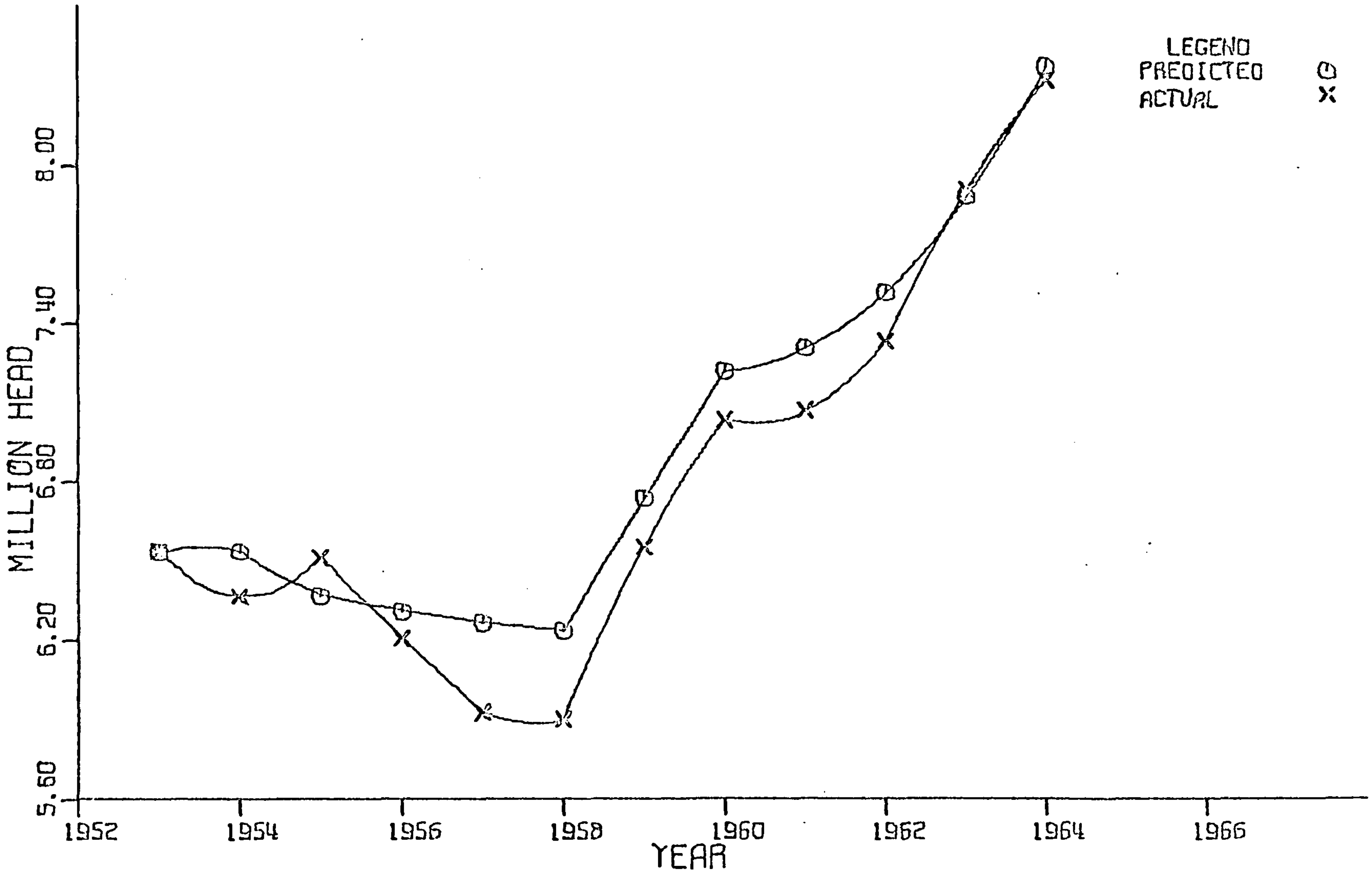

FIGURE 5.5 BEEF HEIFERS ONE TO TWO YEARS OLD JANUARY 1 INVENTORY, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

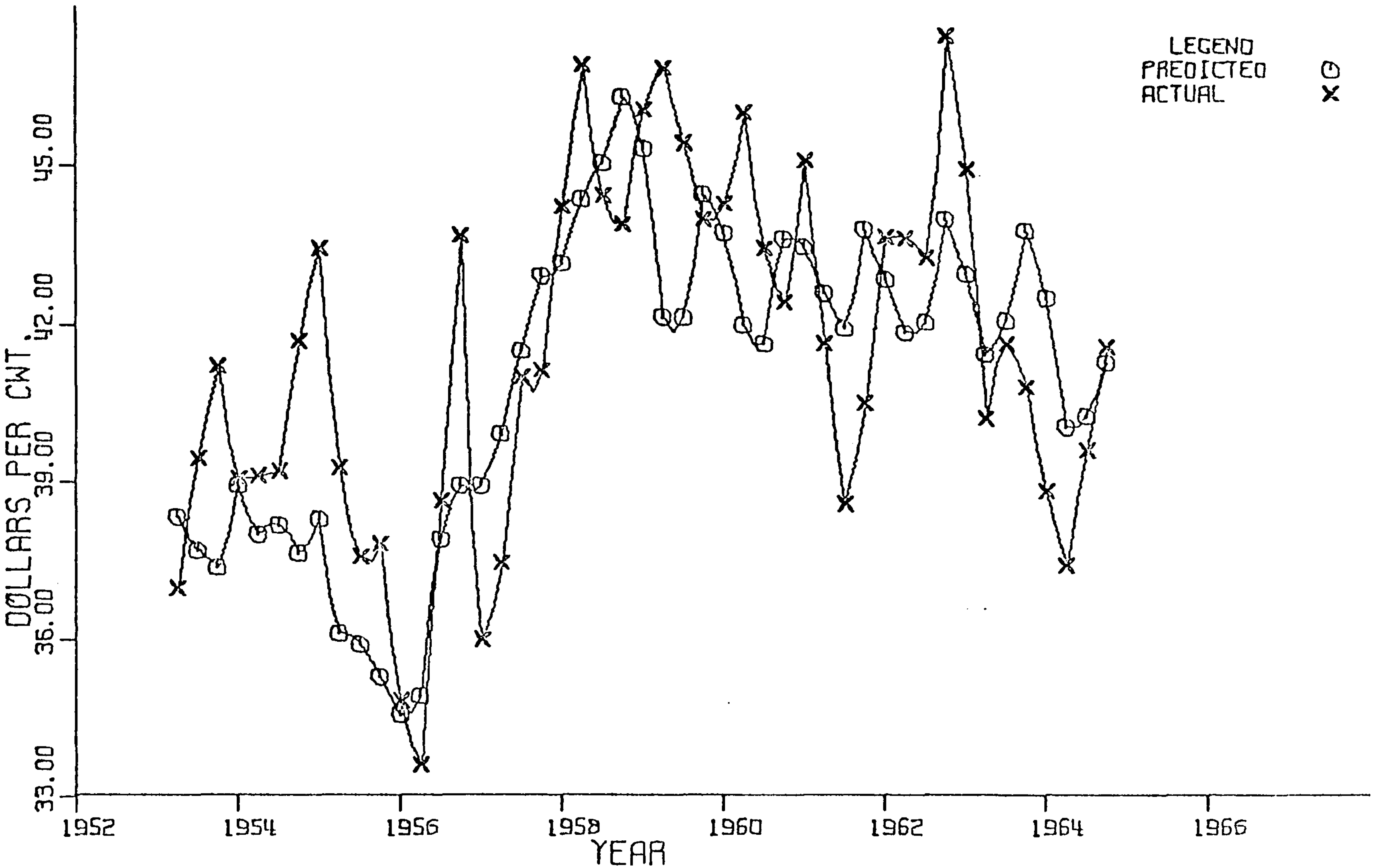

FIGURE 5.6 WHOLESALE BEEF PRICE, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

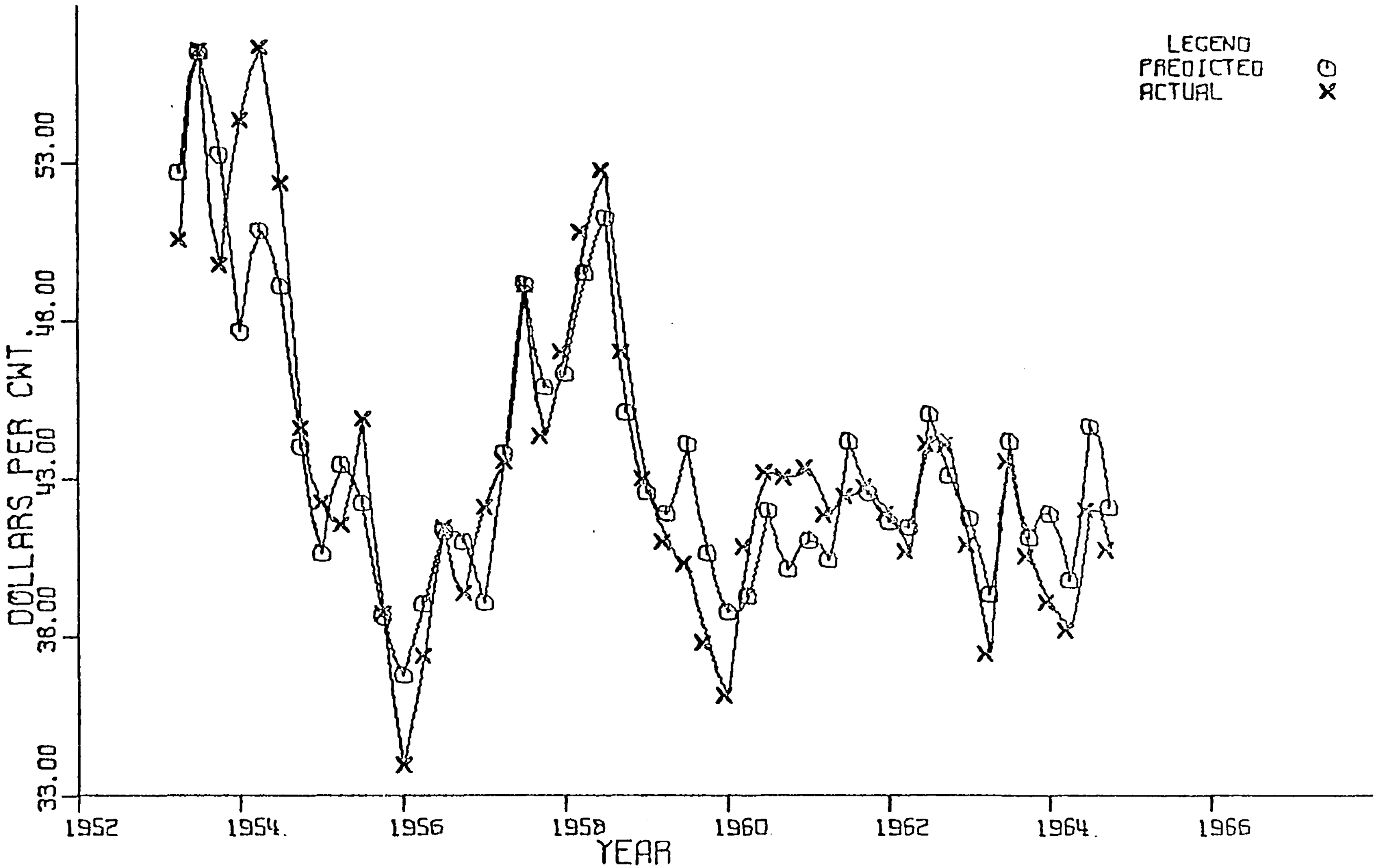

FIGURE 5.7 WHOLESALE PORK PRICE, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

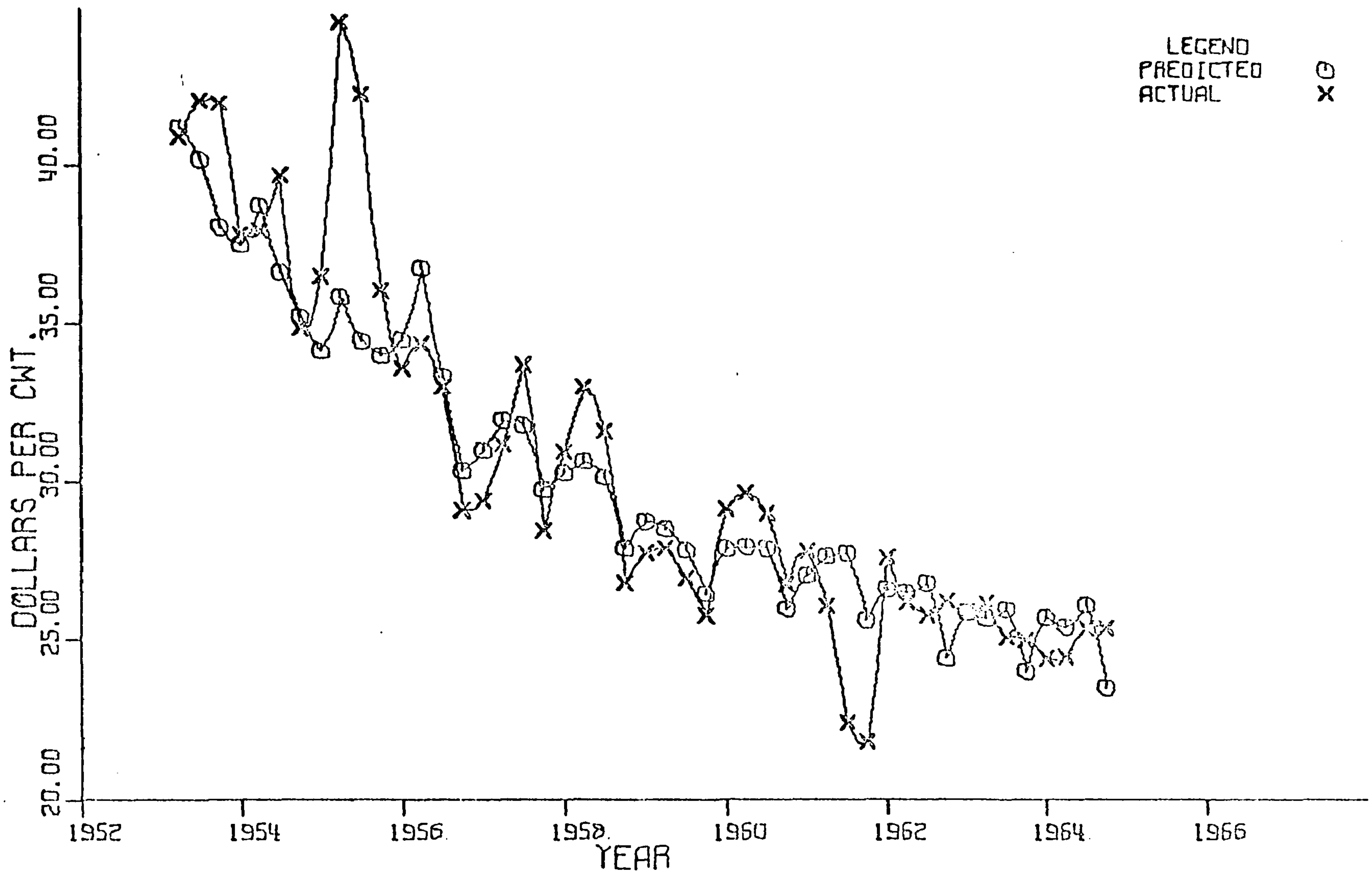

FIGURE 5.8 WHOLESALE BROILER PRICE, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

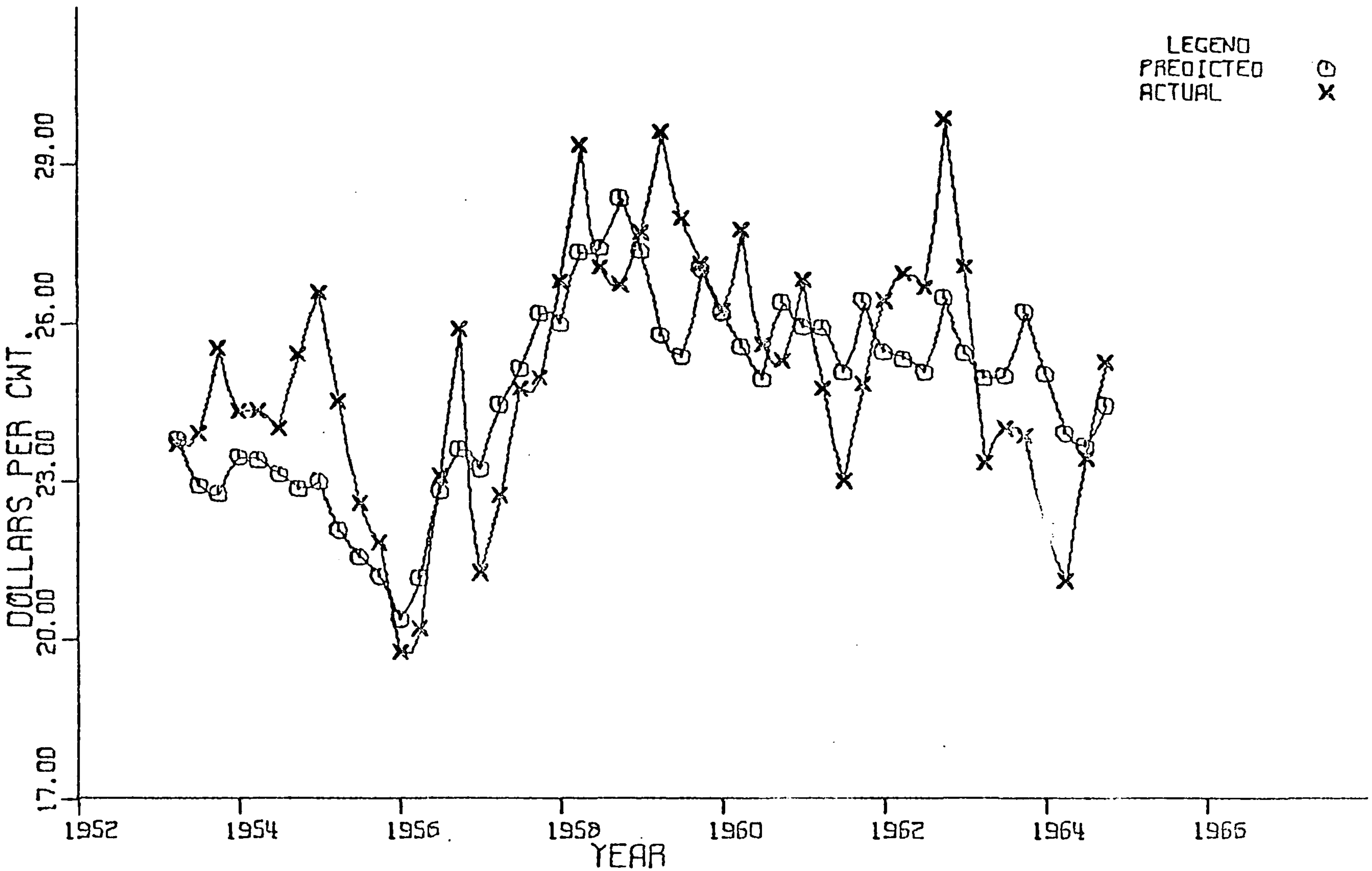

FIGURE 5.9 SLAUGHTER STEER PRICE, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

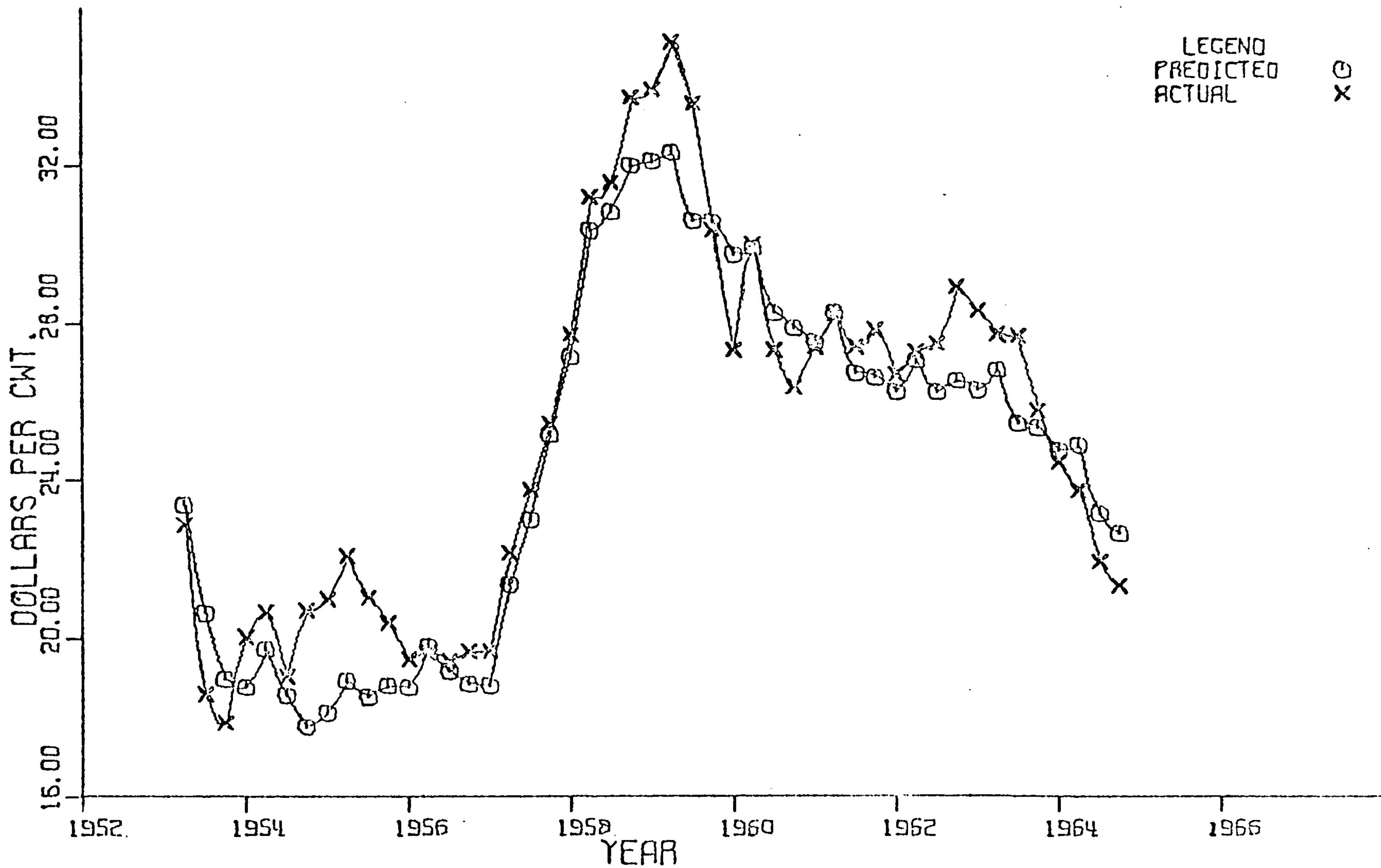

FIGURE 5.10 FEEDER CALF PRICE, ACTUAL, AND PREDICTED BY SIMULATOR
GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

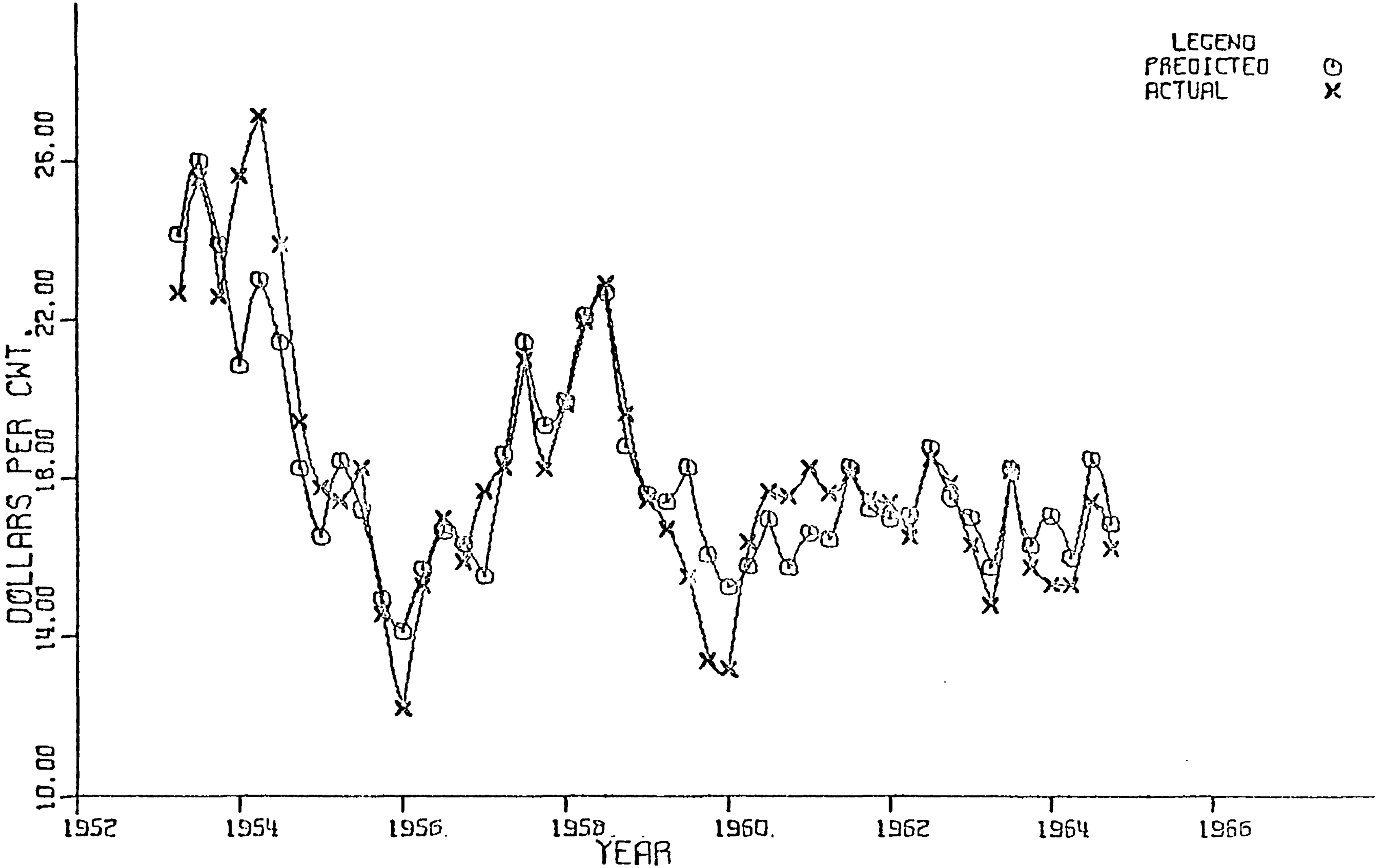

FIGURE 5.11 SLAUGHTER HOG PRICE, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

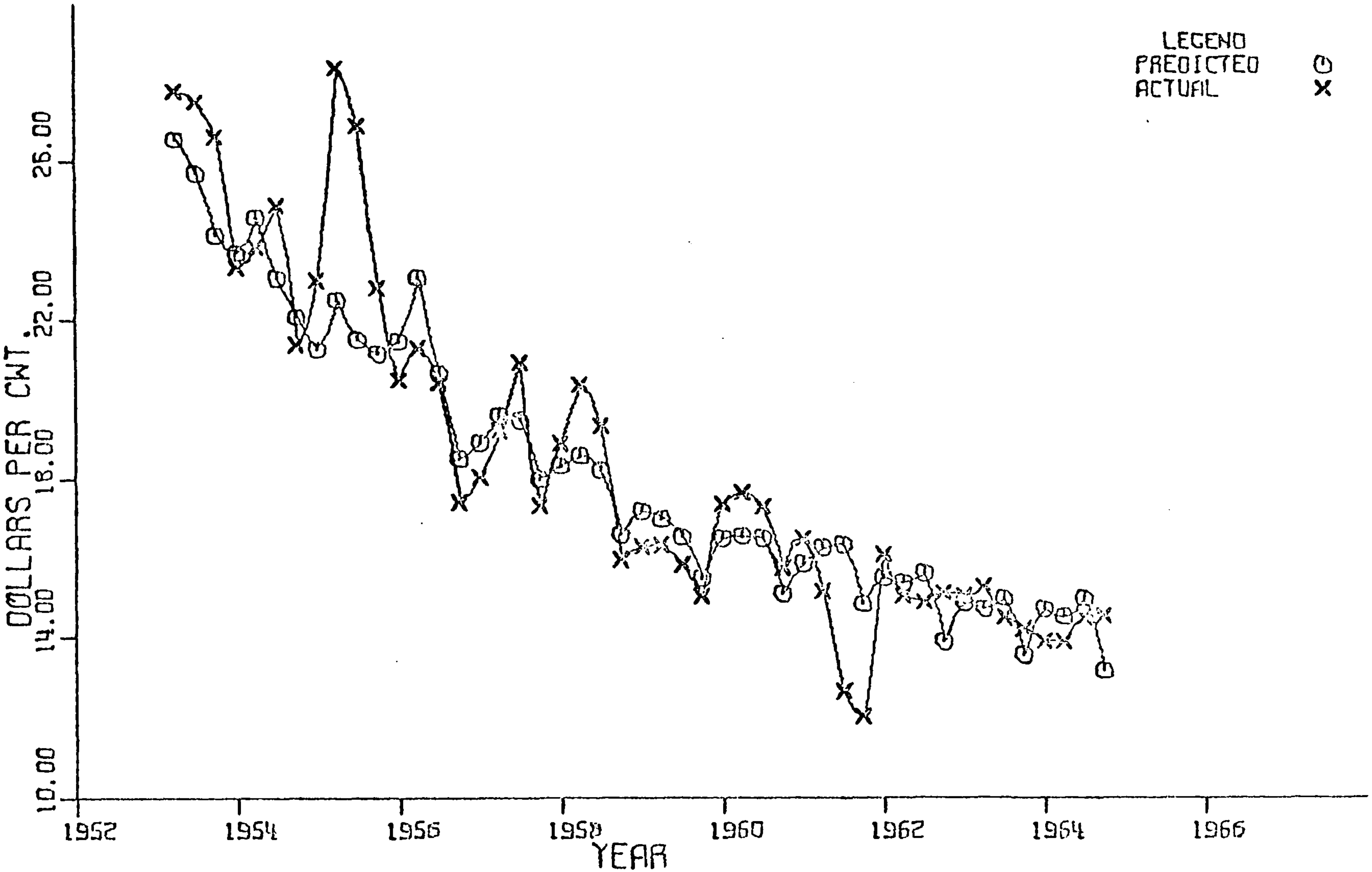

FIGURE 5.12 FARM PRICE BROILERS, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

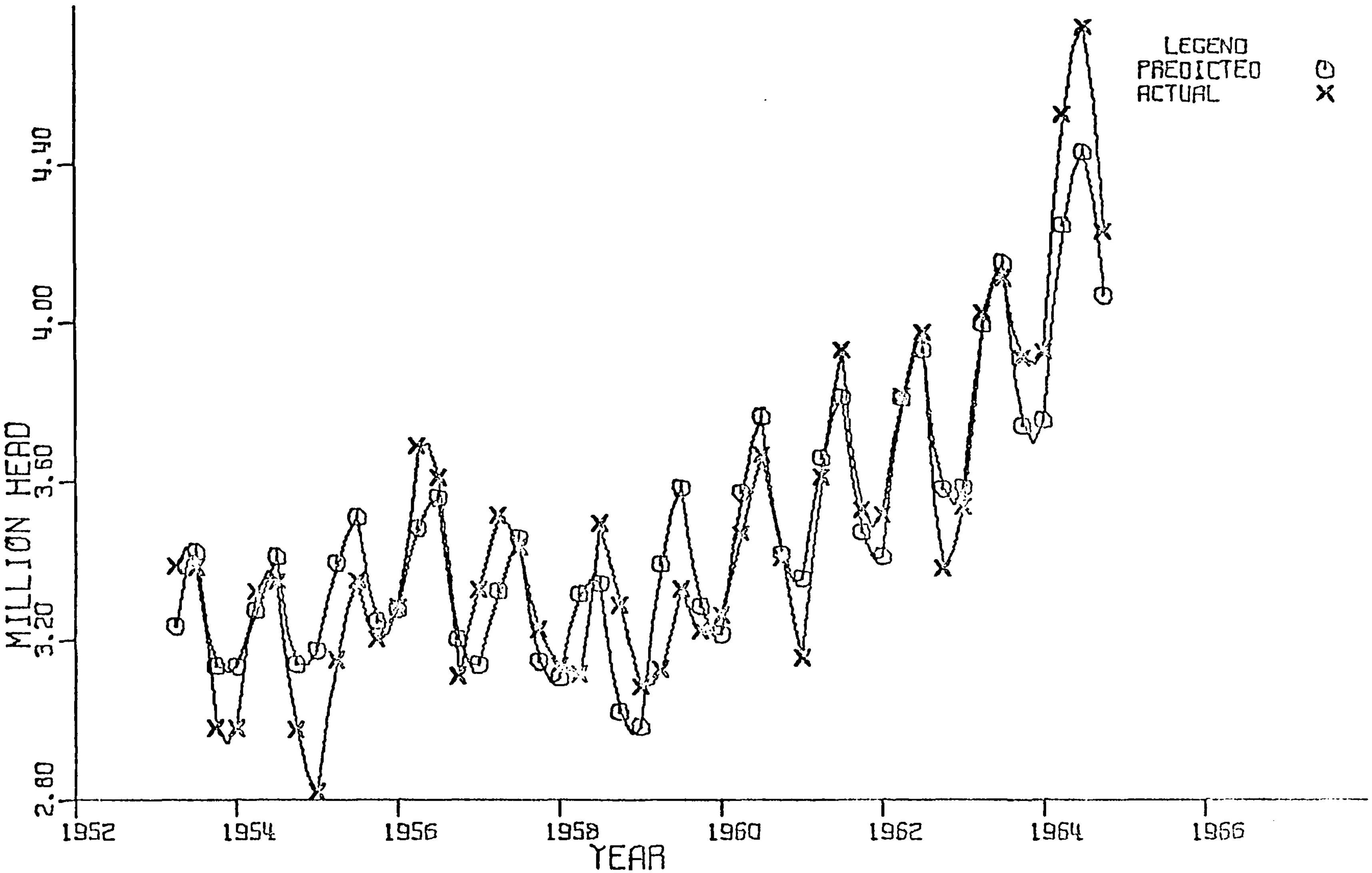

FIGURE 5.13 COMMERCIAL STEER SLAUGHTER, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

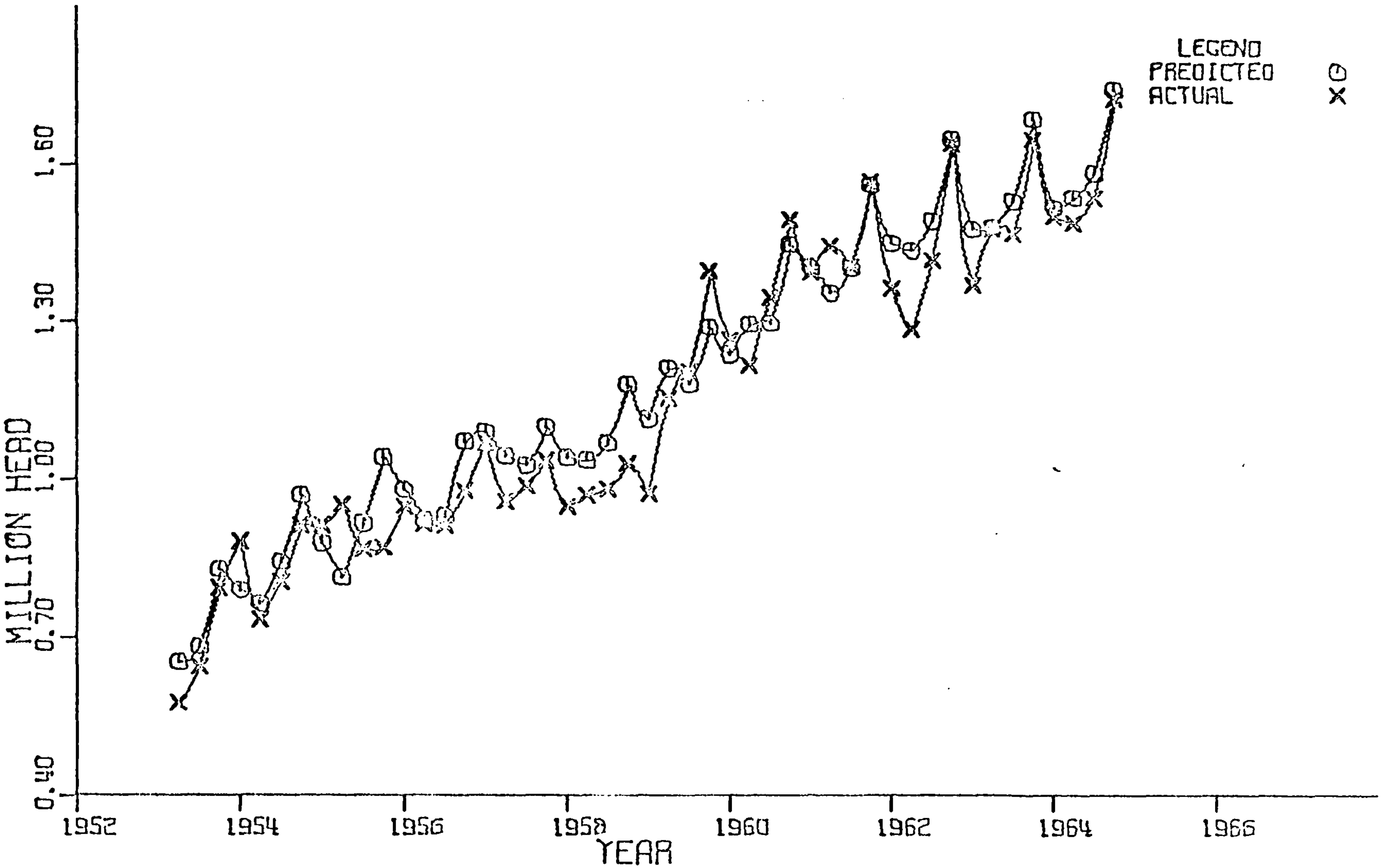

FIGURE 5.14 COMMERCIAL HEIFER SLAUGHTER, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

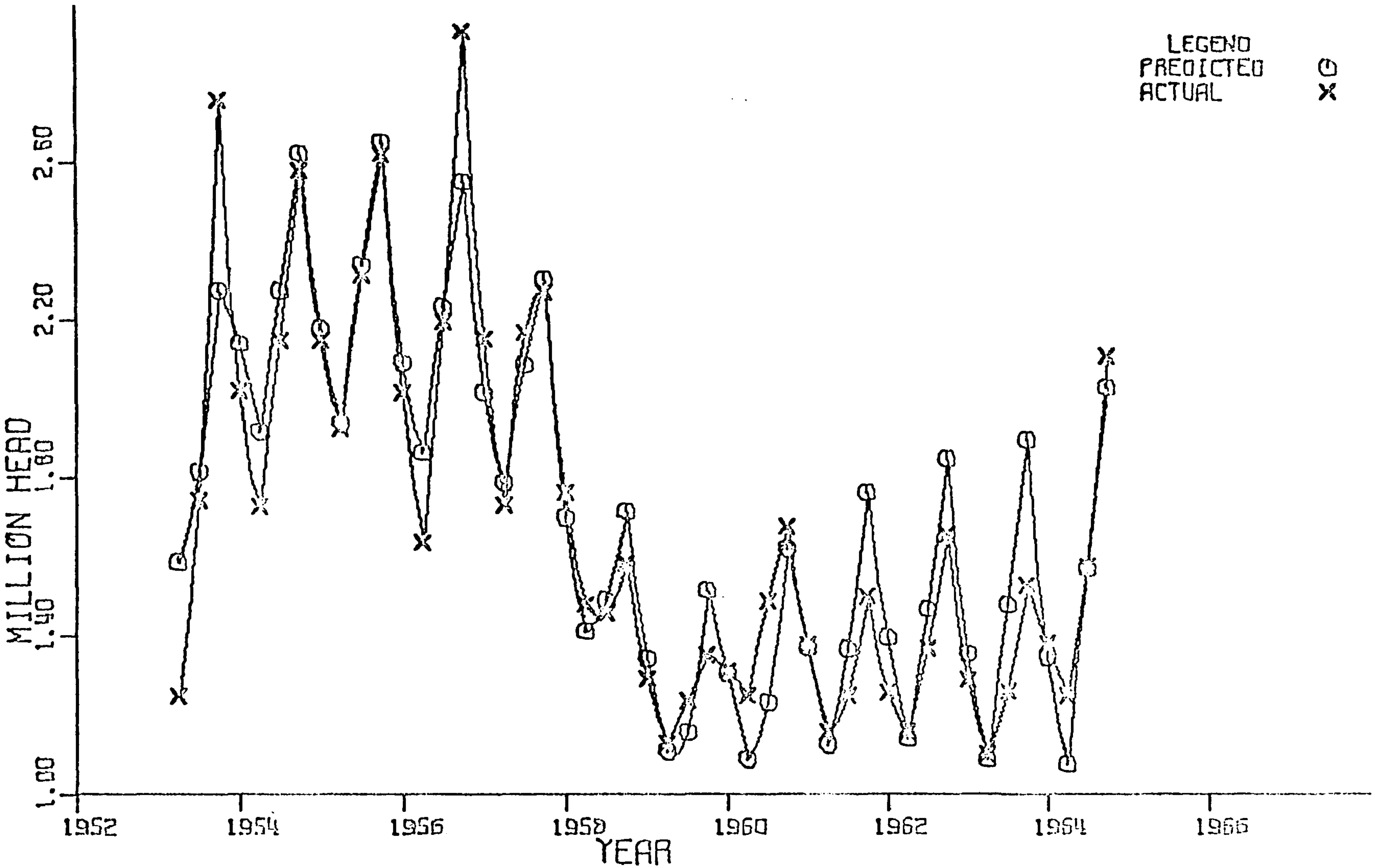

FIGURE 5.15 COMMERCIAL COW SLAUGHTER, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

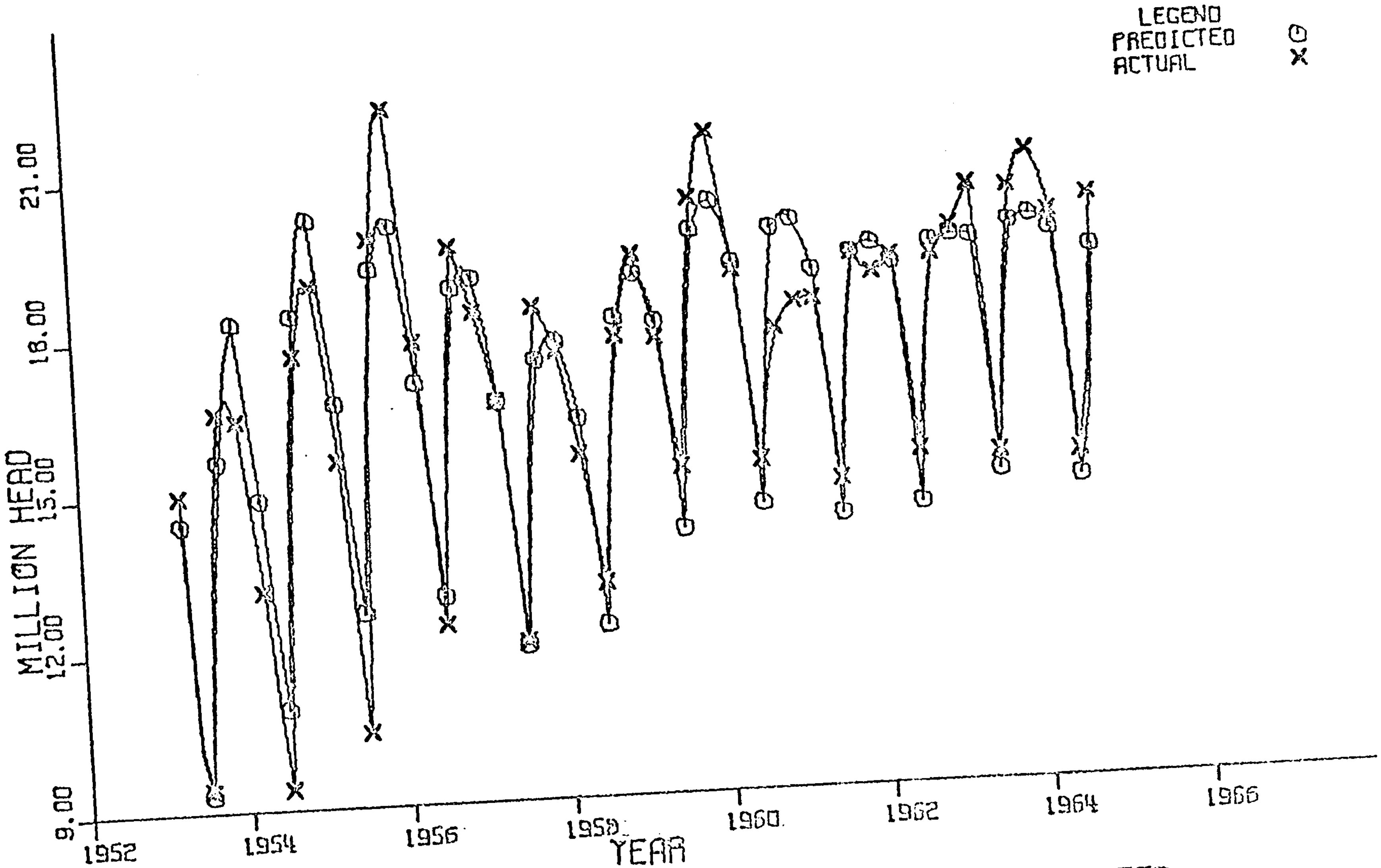

FIGURE 5.16 COMMERCIAL HOG SLAUGHTER, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

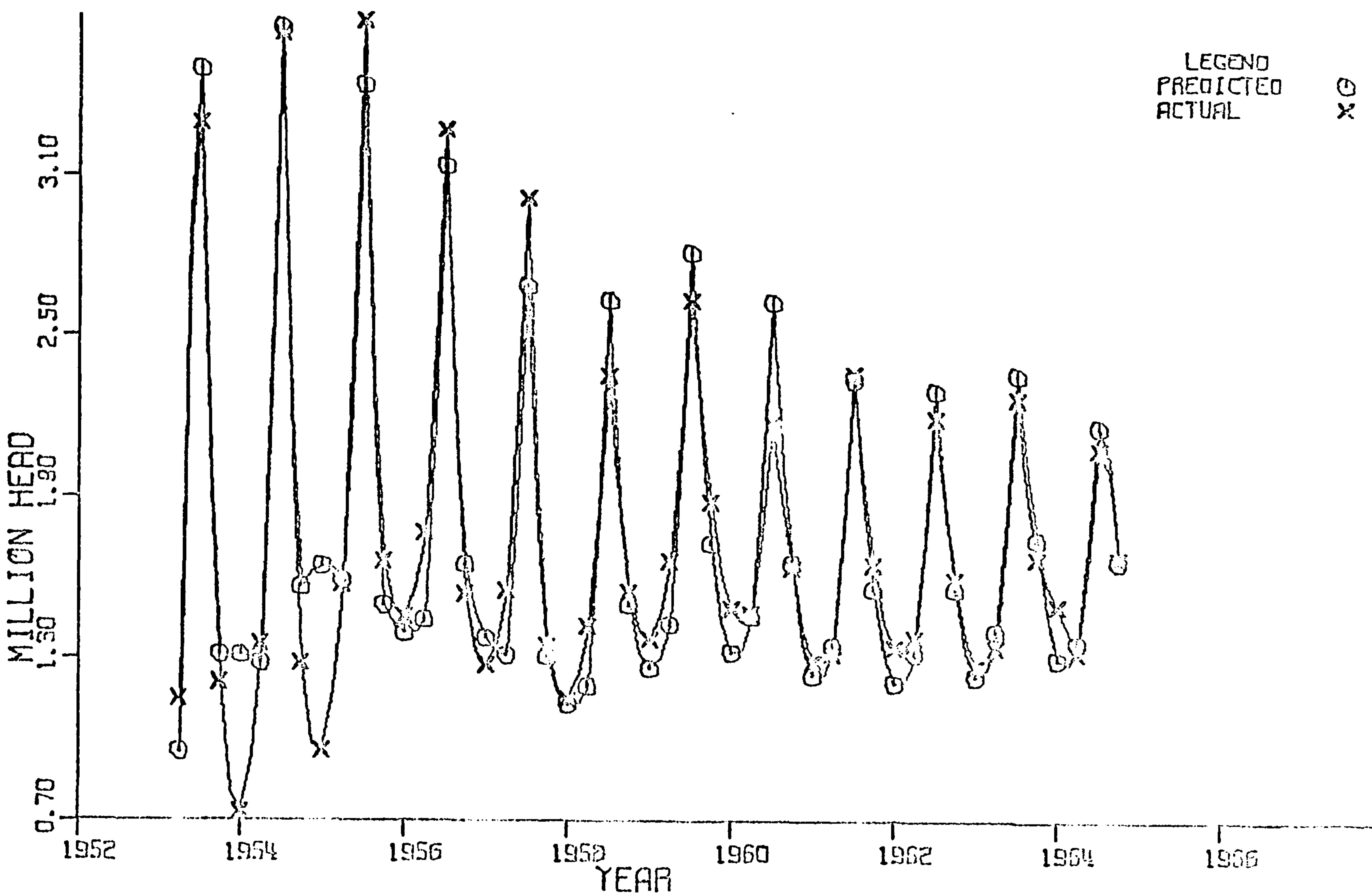

FIGURE 5.17 COMMERCIAL SOW SLAUGHTER, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

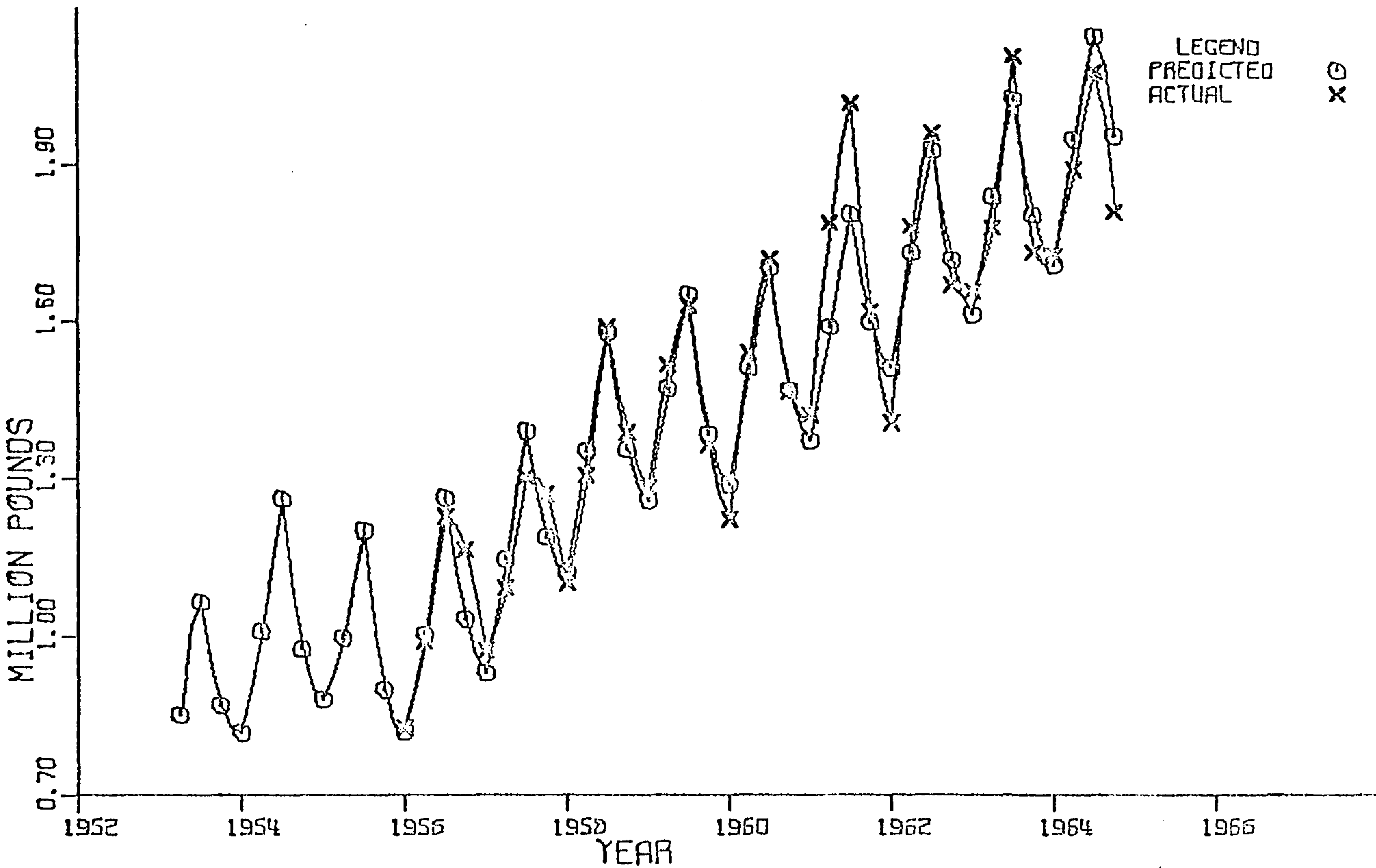

FIGURE 5.18 COMMERCIAL BROILER PRODUCTION, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

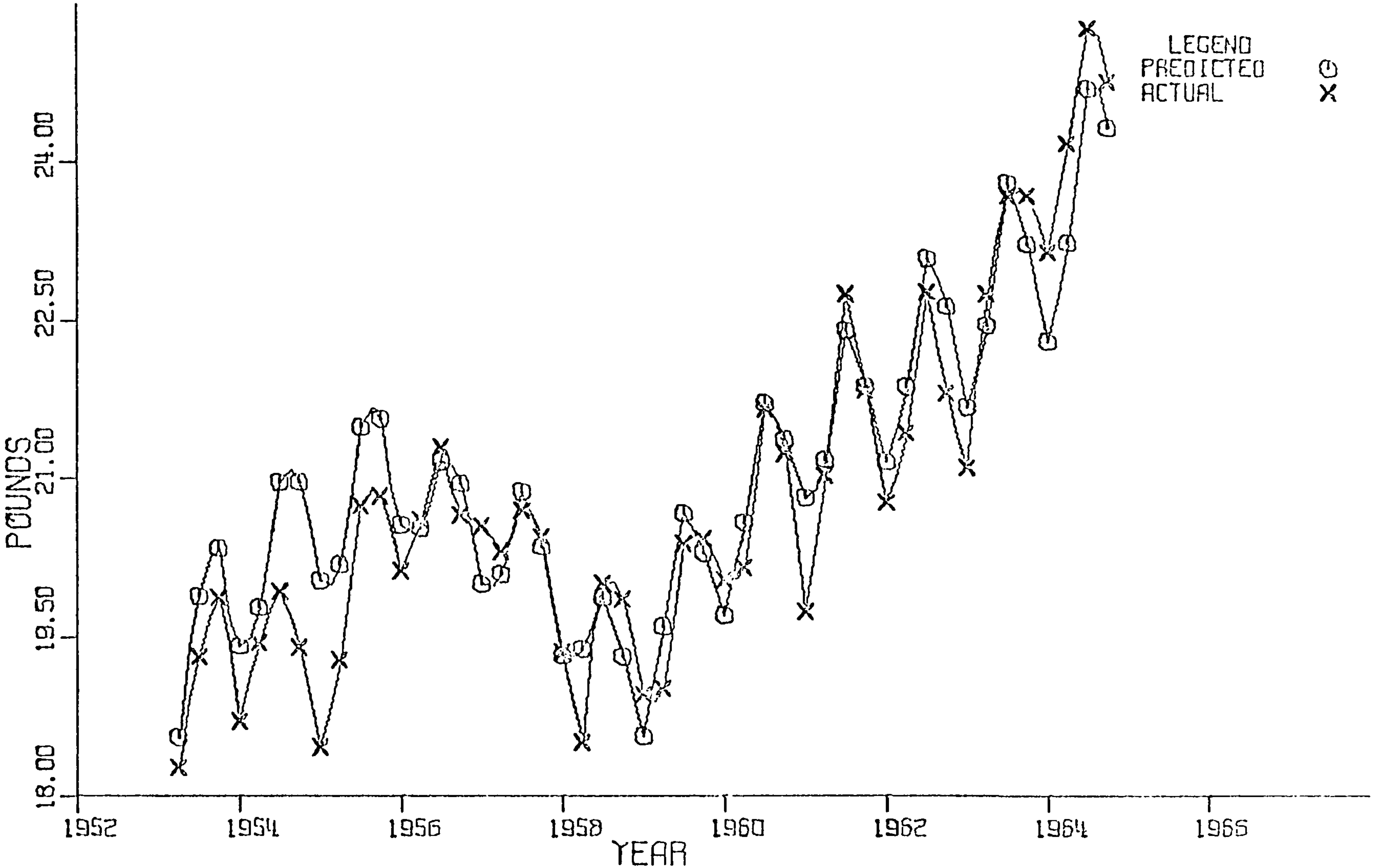

FIGURE 5.19 PER CAPITA BEEF CONSUMPTION, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

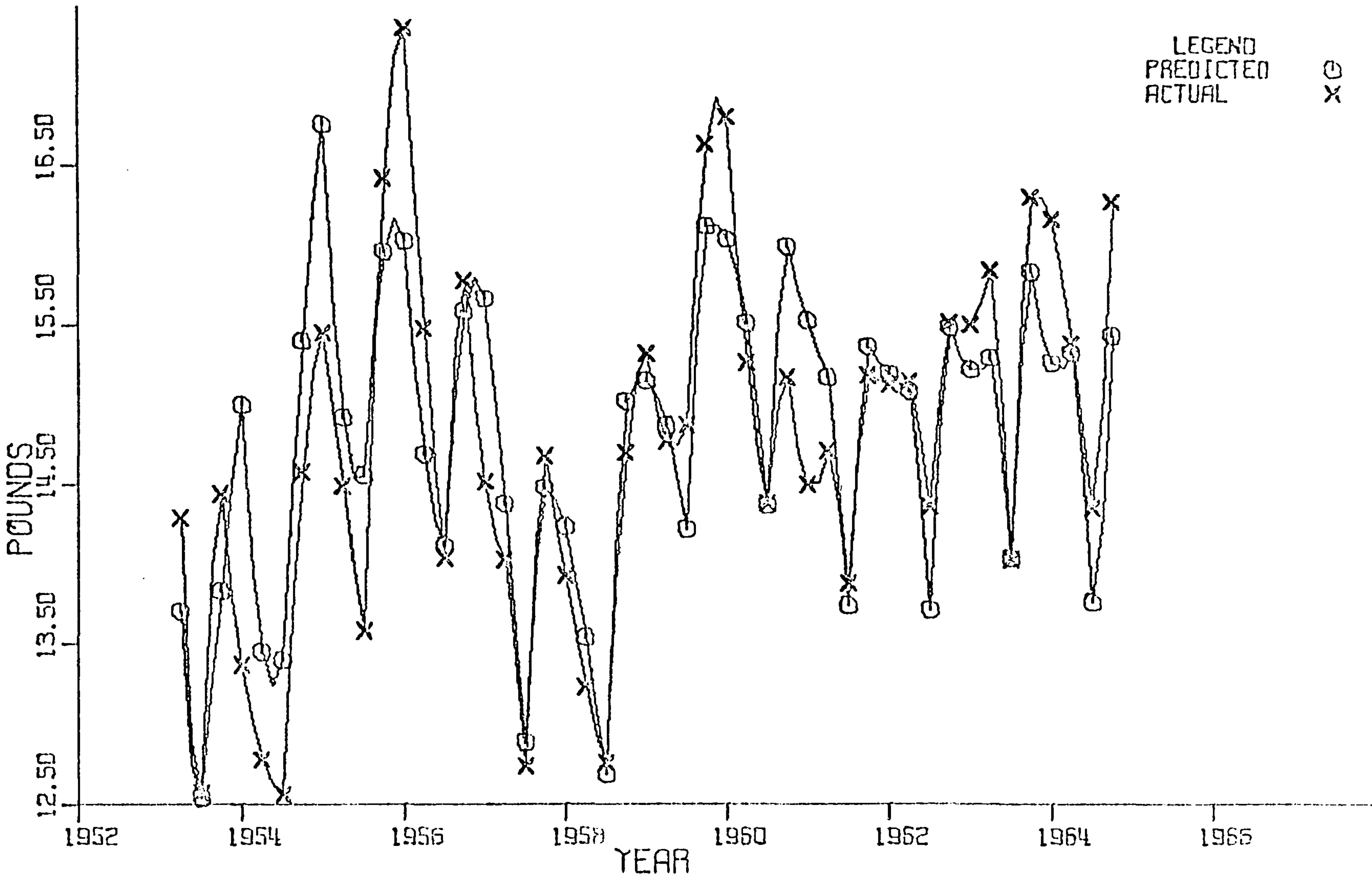

FIGURE 5.20 PER CAPITA PORK CONSUMPTION, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

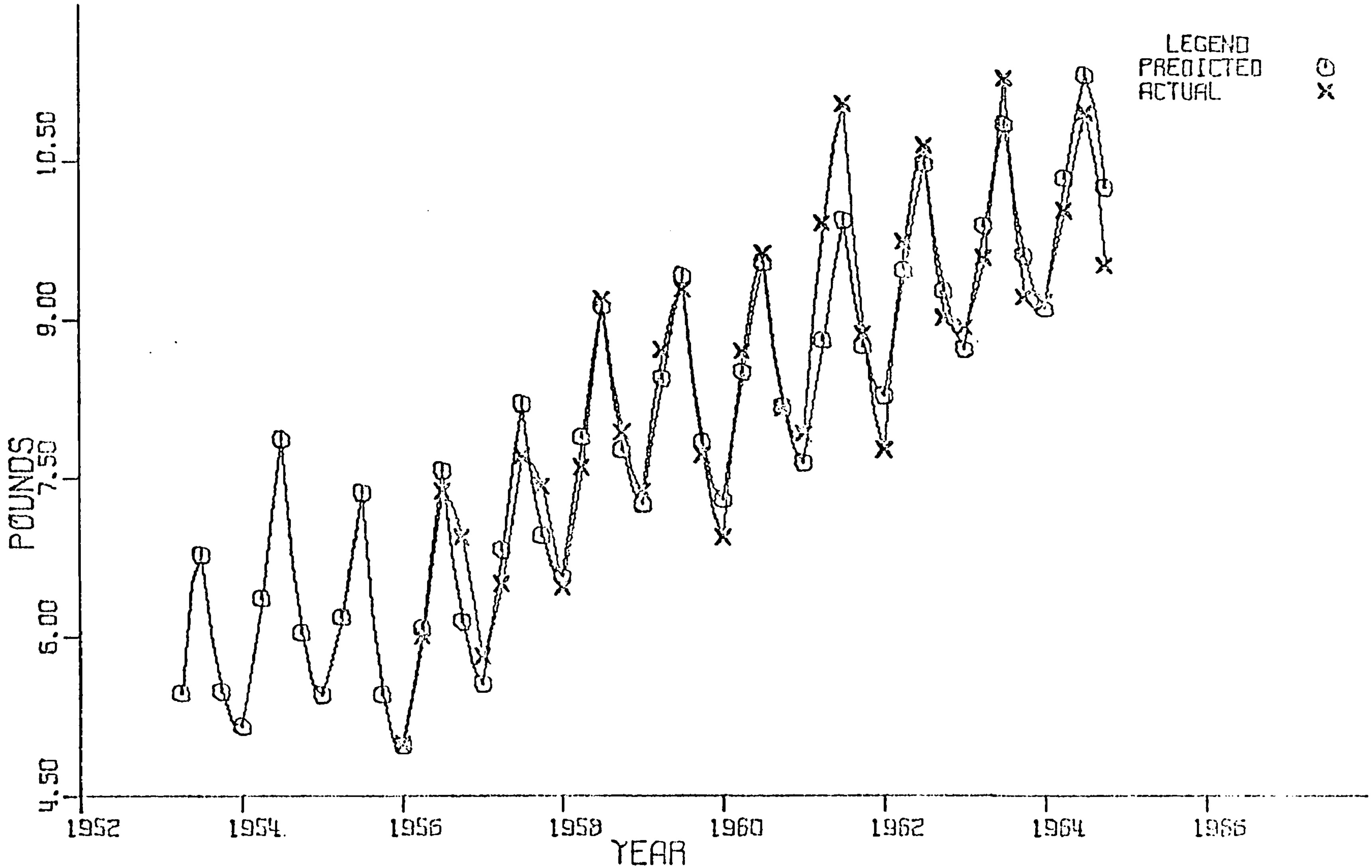

FIGURE 5.21 PER CAPITA BROILER CONSUMPTION, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

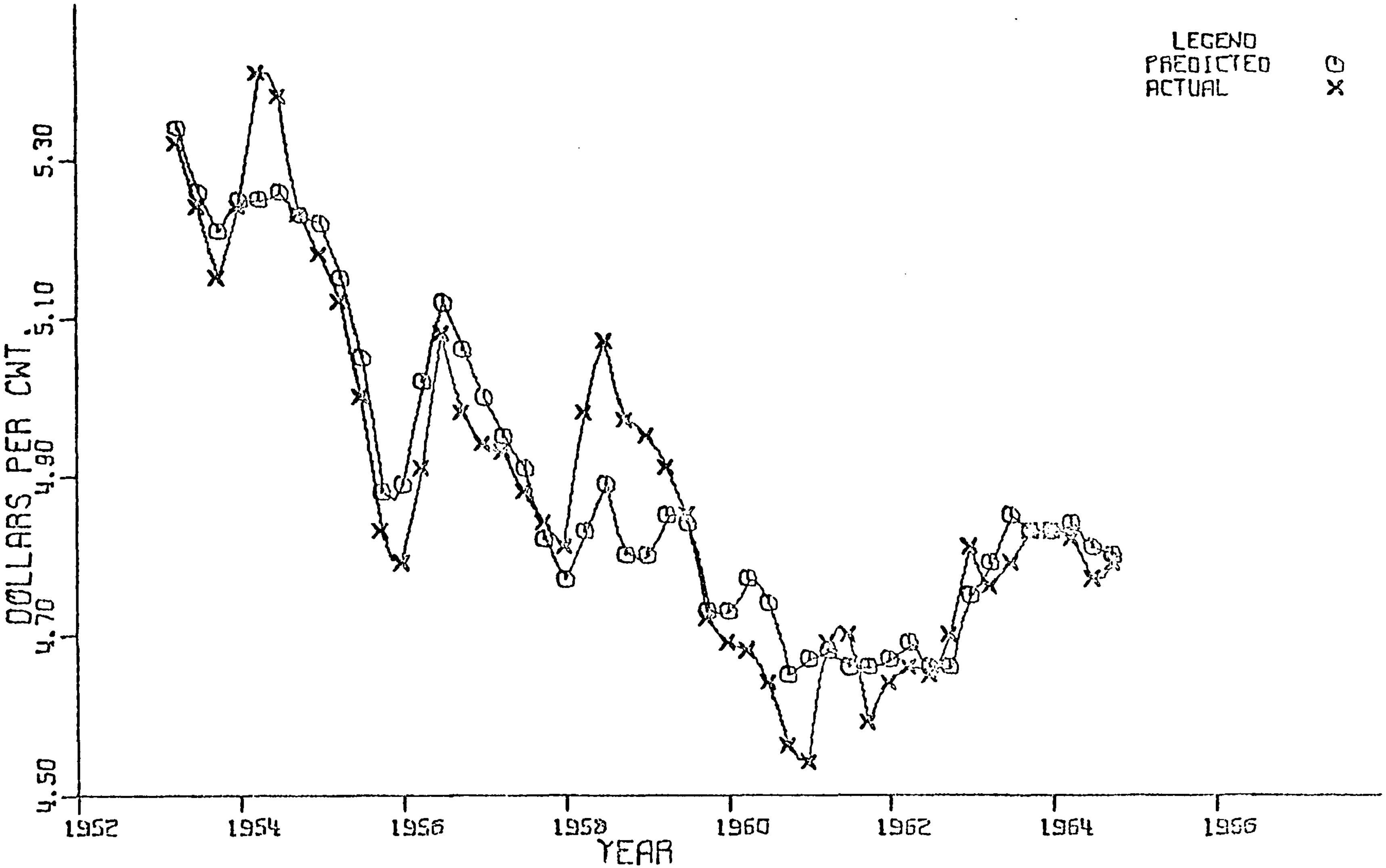

FIGURE 5.22 FARM PRICE BROILER GROWER MASH, ACTUAL, AND PREDICTED BY SIMULATOR GIVEN INITIAL CONDITIONS AND EXOGENNOUS DATA

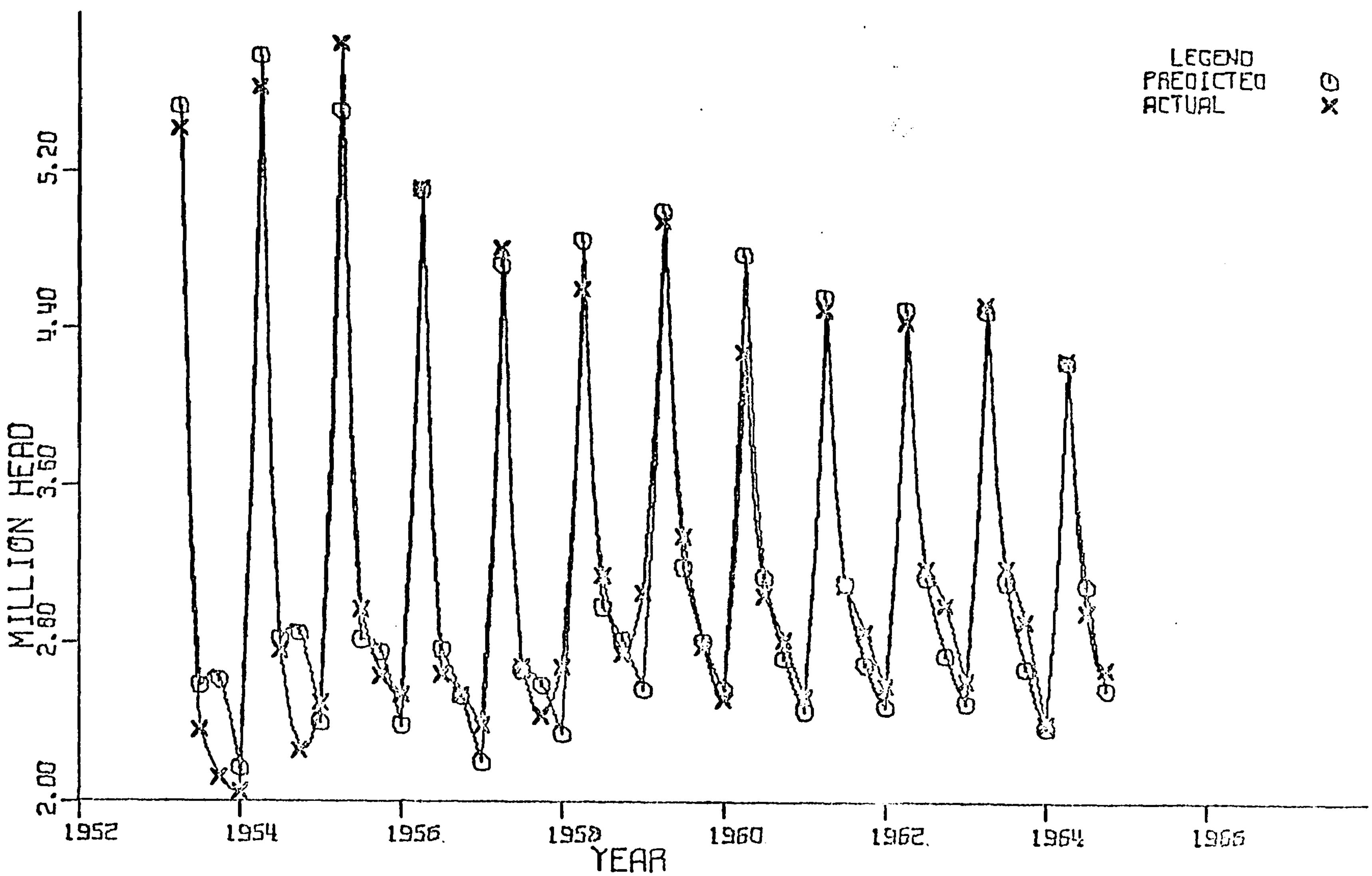

FIGURE 5.23 SOWS FARROWING, ACTUAL, AND SIMULATED GIVEN INITIAL CONDITIONS AND EXOGENOUS DATA

equations were quite similar. In addition, the other regression statistics (S, F, R^2) did not suggest the use of one equation over the others.

Each equation was individually used in the simulation of the historical period. The equations estimated with no a priori restriction on the own price elasticity of demand had coefficients of about -3.8 for the per capita beef consumption variable. Hence, a one pound per capita error in the estimate of the latter variable led to a \$3.80 error in the estimate of wholesale beef price. The corresponding coefficient for the other two equations caused a \$2.50 error in wholesale beef price for a one pound per capita error in the estimate of beef consumption. The sensitivity of the estimates of wholesale beef price to errors in the per capita consumption of beef when the former equations were used had a decided influence on the selection of an equation where the price elasticity for beef was more in accord with that estimated by other researchers. The selection between the two latter equations was based on the ability of the equation with different seasonal elasticities to more accurately reproduce the historical structure of wholesale beef prices.

The model as detailed in the previous chapter, with the several restrictions outlined above, is assumed to be a valid representation of the livestock-meat industry even though the simulation of the historical period is not entirely adequate in all periods for all variables. The over-all structure affords a reasonable representation of the interacting forces within the industry and in general the estimated coefficients are in agreement with economic theory and *a priori* judgments.

In seeking to account for the large errors in prediction for certain periods, it was often found that both the random error of the equation in question and those for several of the predetermined endogenous variables used in its calculation were of the same sign and greater in absolute magnitude than their standard errors. In addition, the estimates of several variables used to estimate these independent variables were often misestimated such that they complemented the random errors. Hence, the estimated values of several predetermined variables were often decidedly biased in the same direction as the random error in the equation being estimated, the sum of the two types of errors yielding a large miscalculation. The large deviation of the variable in question from its historical value could thus not be attributed to any single quantifiable factor. Rather, these errors appear to be the cumulative result of random forces coming together in a non-random manner.

The most powerful test of an empirically estimated model is the degree of accuracy with which it predicts the behavior of the actual system (which is being simulated) outside the range of the data used to estimate its structural coefficients. In this study no data beyond the fourth quarter of 1964 influenced the specification of the model nor were used to estimate any structural coefficients. Hence, the historical data for 1965 and the first two quarters of 1966 can be used to test the model's ability to forecast the future values of its endogenous variables. The historical values of all lagged variables generated in current time periods prior to the first quarter of 1965 were given as initial conditions. In addition, the current exogenous variables were set at their historical levels.

One additional restriction was placed on the model for predicting beyond the fourth quarter of 1964. In August of 1964 the Congress of the United States passed Law 48-82 restricting the imports of meat.[1] A base quota of 725.4 million pounds per year of beef was established. This base is approximately equal to the 1959-1963 annual average imports. Each year an estimate of domestic production is made. The base quota is allowed to increase by the same percentage that domestic beef production increases over the average 1959-1963 production. If anticipated imports exceed 110 percent of the adjustable base, then the President of the United States must take restrictive action. Under such circumstances imports are limited to 100 percent of the adjustable base.

In this study only net imports of beef are estimated. A net base quota of 683 million pounds was established by subtracting the average 1958-1964 annual exports of beef from the actual base. Each quarter the sum of the current and past three quarters beef production was calculated. If this annual production was greater than the 1959-1963 average annual production, then the 683 million pound base

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[1]Rockwell, George R., Jr., Economic and Statistical Analysis Division, Economic Research Service, U.S. Department of Agriculture, Washington, D.C. Data on the 1953 to 1966 United States meat import structure and the meat import restrictions enacted in 1964. Private communication. September 27, 1966.

was increased by the same percentage. The seasonal import structure was incorporated by restricting quarterly imports to the same percentage of the estimated adjustable base as 1958-1964 quarterly imports were of the total for this period. These percentages for the first through fourth quarters, respectively, are: 21.30, 22.25, 30.66 and 25.79.

The actual and predicted values of the 35 endogenous variables for the six quarters and two annual periods outside the range of the initial set of data are given in Figure 5.24 and Table 5.2, respectively. In general the errors in prediction are of about the same

Table 5.2 Actual and predicted values of annual endogenous variables in the livestock-meat economy, United States, 1965 and 1966

Variable code name	Actual or predicted	Year	
		1965	1966
CBS	A	32,883	32,636
	P	33,458	34,945
CVS	A	25,133	25,927
	P	25,581	26,984
STS	A	11,926	12,668
	P	12,376	12,804
HES	A	8,513	8,341
	P	8,880	9,178
SHS	A	20,439	21,009
	P	21,257	21,983

order as was observed in the simulation of the historical period. However, two serious shortcomings are evident. The first is the

VARIABLE CODE NAME	ACTUAL OR PREDICTED	YEAR AND QUARTER 1965 1	1965 2	1965 3	1965 4	1966 1	1966 2
BSN	A	1.336	1.071	0.932	1.220	1.285	1.065
	P	1.220	1.034	1.017	1.191	1.034	0.970
PSN	A	0.134	0.105	0.101	0.114	0.096	0.080
	P	0.099	0.101	0.115	0.143	0.122	0.119
BRSN	A	1.672	1.536	0.703	0.737	0.964	1.386
	P	1.511	1.958	1.013	1.041	1.344	1.895
BCN	A	23.84	23.80	24.66	25.08	24.70	24.64
	P	23.29	23.57	25.20	24.62	23.20	23.67
PCN	A	15.40	14.95	13.07	14.27	12.79	14.13
	P	15.31	15.56	13.72	15.07	14.64	14.90
BRCN	A	9.17	10.28	11.78	10.51	10.23	11.18
	P	9.52	10.59	11.71	10.71	10.39	11.50
BPW	A	39.88	41.92	44.64	42.61	43.85	44.66
	P	40.93	41.12	41.50	42.24	42.34	42.50
PPW	A	40.31	43.65	53.29	53.66	61.45	54.02
	P	43.45	40.50	47.96	47.34	50.35	46.75
BRP	A	25.20	26.50	26.67	25.37	27.37	28.83
	P	25.25	25.48	25.99	23.72	24.18	24.97
SP	A	24.10	25.61	27.26	26.76	26.55	28.33
	P	24.18	24.69	24.50	25.06	24.78	25.37

FIGURE 5.24 ACTUAL AND PREDICTED VALUES OF QUARTERLY ENDOGENOUS VARIABLES IN THE LIVESTOCK-MEAT ECONOMY, UNITED STATES, FIRST QUARTER 1965 TO SECOND QUARTER 1966

VARIABLE CODE NAME	ACTUAL OR PREDICTED	1965 1	1965 2	1965 3	1965 4	1966 1	1966 2
		YEAR AND QUARTER					
SFP	A	21.18	23.27	24.30	24.56	26.74	29.41
	P	20.89	21.99	21.82	22.37	22.93	24.42
HP	A	17.04	19.05	24.72	24.26	28.90	24.52
	P	18.01	16.39	20.51	20.04	22.23	20.20
BRF	A	14.43	15.33	15.47	14.43	15.70	16.60
	P	14.38	14.51	14.88	13.25	13.55	14.07
HEQ	A	1578.	1700.	1830.	2171.	1946.	2037.
	P	1552.	1594.	1643.	1845.	1673.	1618.
STQ	A	4220.	4276.	4184.	3853.	3996.	4209.
	P	4205.	4530.	4683.	4217.	4246.	4725.
SHQ	A	5798.	5976.	6014.	6024.	5942.	6246.
	P	5757.	6125.	6331.	6062.	5919.	6343.
COQ	A	1799.	1607.	2096.	2467.	2121.	1776.
	P	1447.	1147.	1790.	2206.	1356.	1017.
HQ	A	19269.	18290.	14390.	17485.	15806.	17254.
	P	18454.	19517.	14260.	18217.	18054.	18635.
SQ	A	1416.	1316.	1652.	1338.	1050.	1281.
	P	1335.	1232.	2023.	1580.	1091.	1172.
CAAW	A	1022.	1007.	984.	988.	1020.	1011.
	P	1038.	1039.	1006.	1003.	1049.	1053.

FIGURE 5.24 (CONTINUED)

VARIABLE CODE NAME	ACTUAL OR PREDICTED	YEAR AND QUARTER 1965 1	1965 2	1965 3	1965 4	1966 1	1966 2
ZAW	A	237.7	237.0	239.7	238.3	241.0	243.3
	P	244.7	245.0	246.4	241.1	245.3	247.0
CY	A	57.3	57.7	57.3	56.7	56.9	57.5
	P	57.7	58.5	57.9	57.1	57.9	58.7
BQ	A	4461.	4422.	4617.	4795.	4704.	4689.
	P	4314.	4416.	4756.	4757.	4410.	4549.
PQ	A	3005.	2850.	2365.	2770.	2499.	2803.
	P	2957.	3079.	2459.	2928.	2873.	2978.
CAQ	A	7692.	7693.	8259.	8632.	8182.	8147.
	P	7266.	7345.	8236.	8374.	7327.	7421.
ZAQ	A	20848.	19731.	16150.	18930.	16947.	18567.
	P	19900.	20871.	16422.	19887.	19239.	19920.
BRGP	A	4.82	4.81	4.87	4.81	4.84	4.87
	P	4.87	4.93	4.90	4.82	4.88	4.88
BTN	A	0.833	1.097	1.203	1.298	1.135	1.034
	P	0.935	0.973	1.144	0.929	0.943	0.990
SFQ	A	2208.	3727.	2661.	2561.	2334.	4084.
	P	2144.	4000.	2926.	2500.	2187.	4163.
BRQ	A	1752.	1963.	2261.	2026.	1970.	2158.
	P	1812.	2028.	2250.	2068.	2002.	2223.

FIGURE 5.24 (CONTINUED)

inability of the model to predict the turning point in the cattle cycle and the second is the failure to estimate the high pork price in the first quarter of 1966.

The overestimation of the January 1, 1965 and 1966 beef cow inventory appears to be a consequence of the higher than normal feeder calf prices for this stage of the cattle cycle. At the peak of the 1955 beef cow inventory cycle, feeder calf prices were some $8 to $10 per hundredweight less than in 1966. The million head error in the 1966 calf inventory is a direct consequence of the error in estimating the 1965 beef cow inventory.

The inability to predict the turning point in the cattle cycle is further manifested in the large underestimation of first and second quarter 1966 cow slaughter. The first difference on the 1965 to 1966 estimated beef cow inventory reduces the estimated cow slaughter by about 100 thousand head at a time when its effect should be working in the opposite direction. The major reason for the errors in the estimates of cow slaughter, however, is the abnormally high price of feeder calves for this stage of the cattle cycle.

The influence of the aberrant estimates of 1966 cow slaughter is partly mitigated by the very accurate estimates of the sum of steer and heifer slaughter in this period. Since the average weight per head of all cattle is highly influenced by the proportion of cows to steers and heifers slaughtered, a large overestimation of average weight per head results. This tends to offset a part of the consequence of underestimating total cattle numbers in the determination of beef production.

The major reason for the low estimate of wholesale pork price relative to its historical value during the first quarter of 1966 is the small number of sows farrowing in the second and third quarters of 1965 relative to what was expected based on past behavior. The error of 273,000 head in the estimate of second quarter farrowings causes 738,000 of the 2,248,000 head error in the estimate of first quarter hog slaughter (2.704 x 273,000), while the misestimate of 265,000 head in third quarter 1965 farrowings accounts for an additional 470,000 head.

Even though per capita broiler consumption is very accurately estimated for the six quarters of projection, the estimates of wholesale broiler price in 1966 are not entirely satisfactory. The errors in these two quarters are directly attributable to the low estimates of wholesale pork price during this period. In the wholesale demand relationship (Equation 4.31) broiler price increases $.342 for every dollar increase in pork price. Hence, in the first quarter of 1966, the $11.10 error in pork price reduces the estimate of wholesale broiler price by $3.80.

Projections of Livestock-Meat Economy to 1969

One use of the simulation model is to predict the future values of the endogenous variables in the livestock-meat economy. These projections were made from the third quarter of 1966 through the fourth quarter of 1969. The historical values of the lagged variables up to and including the second quarter of 1966 were supplied as initial conditions. Rather than using known values of the exogenous variables, it was necessary to make informed "guesses" of their values. The values of the exogenous variables are thus an additional potential source of error in the simulation of the true values of the endogenous variables in the system.

<u>Estimation of exogenous variables</u>[1]

Aside from the trend variable and the several constructs of dummy variables which follow a repetitive pattern, 10 exogenous variables of economic substance are used in the livestock-meat model. Quarterly domestic civilian population is a central variable in the operation of the model. Within a short period of time population growth can be approximated by a linear trend. Data for the most recent 20 quarters (third quarter 1961 through the second quarter 1966) were used in the least squares estimation of population as a function of time given in Equation 5.1.

$$P_t = 158{,}481 + \underset{(87.0)}{655.863}T_t$$

$$S = 194 \qquad R^2 = .998 \qquad \rho = 0 \qquad d = 0.47 \qquad (5.1)$$

During the past several quarters domestic civilian population has not grown at the rate estimated for the entire period. This underestimation of civilian population is partly a consequence of the build-up in military personnel. To correct for this effect the constant term of Equation 5.1 is adjusted to 157,727 so that the estimate of third

[1]The estimated values of the exogenous variables for the period of projection are given in Table A.2 in the appendix.

quarter 1966 domestic civilian population corresponds to the published July, 1966, estimate. It is then assumed that civilian population will grow at the same rate as the average for the previous 5 years.

The military consumption of beef and pork are assumed to remain at the average per capita civilian values of the past 2 years. A constant ratio of military consumption to civilian population implicitly assumes a slight increase in military demand. Net imports of pork are also assumed to remain at the average per capita levels of the past 2 years.

During the most recent eight quarters per capita personal disposable income has exceeded the average growth as measured by trend, by an increased amount each quarter. The second quarter 1966 estimate of residual per capita personal disposable income of $213.39 is approximately four times greater than any deviation from trend observed during the period for which the trend was estimated. The transition of the economy to full employment has undoubtedly been a significant factor in this high rate of growth in income. It is unlikely that this variable will return to its past trend level in the foreseeable future. The third quarter 1966 estimate of $220.00 is based on July and August, 1966, actual data. It is assumed that residual per capita personal disposable income will decline from this peak to a value of $200.00 by the second quarter of 1967. It is then assumed to remain at this level for the duration of the period of projection. In effect this amounts to assuming the same rate of growth of per capita personal disposable income, but at a level $200.00 higher.

The consumer price index is also assumed to have shifted to a higher level. The residual consumer price index is assumed to be 1.00 for all quarters starting in the second quarter of 1967. The food marketing wage rate does not appear to have experienced any significant change from its trend value. With the exception of estimates of \$.02 and \$.01 for the third and fourth quarters of 1966, this variable is given a zero value for all remaining periods.

The range feed condition is assumed to be at the levels estimated by averaging the most recent 10 years' data by quarter (including the third quarter 1966). A seasonal pattern is thus incorporated into the projected values based on the average historical seasonal structure.

The January 1 dairy cow inventory has declined in a rather systematic manner since 1954. It is assumed that this reduction in numbers will continue at the same rate over the next 5 years. Hence, the 1967 through 1969 dairy cow inventory is projected from the coefficients of Equation 5.2, which were estimated by least squares regression from 1954 to 1966 data.

$$CDS_y = 26{,}776 - \underset{(-21.2)}{594.9}T_y$$

$$S = 379 \qquad R^2 = .976 \qquad \rho = 0 \qquad d = 0.67 \qquad (5.2)$$

It is anticipated that the price of corn will undergo a slight seasonal decline from the third to fourth quarters of 1966. It is then expected to rise to a high of \$1.54 per bushel in the third quarter of 1967 due to the relatively small 1966 crop. It is anticipated that Government policy will be directed at encouraging a substantially increased crop in 1967. Hence, a drop in price of about $.20 per bushel between the third and fourth quarters of 1967 is assumed. Policy is then expected to be implemented such that the general level of price will decline over the next 2 years to $1.15 per bushel in the fourth quarter 1969. In the intervening quarters a seasonal pattern similar to that experienced between 1957 and 1961 is incorporated.

Simulated endogenous variables

The projected values of the 30 quarterly and five annual endogenous variables from the third quarter 1966 to the fourth quarter 1969 are given in Figure 5.25 and Table 5.3, respectively. The results indicate that the January 1 beef cow inventory will increase

Table 5.3 Projected values of annual endogenous variables in the livestock-meat economy, United States, 1967 to 1969

Year	CBS	CVS	STS	HES	SHS
1967	33,383	26,449	13,781	9,219	23,000
1968	35,140	27,581	14,320	9,923	24,243
1969	37,495	29,105	14,852	10,351	25,202

by a substantial amount between 1966 and 1969. During late 1967 and early 1968 the wholesale price of beef is estimated to be near $49.00 per hundredweight, a level which has not existed since 1952. Pork, however, is expected to decline from the current wholesale price of $54.02 per hundredweight to a general level of $45.00 in late 1967 and early 1968.

YEAR AND QUARTER		BSN	PSN	BRSN	BCN	PCN	BRCN	BPW	PPW	BRP	SP
1966	3	0.889	0.945	0.126	24.82	12.77	12.97	43.32	54.41	26.07	26.29
	4	1.006	1.164	0.168	23.60	15.22	11.83	46.50	49.09	22.57	28.16
1967	1	0.880	1.663	0.151	21.49	15.23	11.33	48.77	50.14	23.14	29.19
	2	0.927	2.301	0.139	22.25	16.10	12.36	47.65	45.51	22.26	28.88
	3	0.997	1.590	0.132	23.58	15.10	13.10	47.81	45.85	23.55	28.56
	4	1.264	1.750	0.143	23.29	17.15	12.02	48.97	42.25	20.44	29.41
1968	1	1.205	2.093	0.109	22.21	16.66	11.36	48.41	44.80	21.63	28.70
	2	1.181	2.420	0.097	23.42	16.55	12.34	46.06	44.14	21.60	27.64
	3	1.171	1.410	0.101	25.14	14.70	13.20	45.16	47.54	23.27	26.64
	4	1.363	1.370	0.134	24.88	16.39	12.27	46.21	45.20	20.16	27.44
1969	1	1.263	1.702	0.122	23.63	16.10	11.72	46.33	47.00	21.06	27.20
	2	1.219	2.208	0.121	24.69	15.16	12.72	44.66	45.71	21.00	26.61
	3	1.238	1.367	0.120	25.77	14.25	13.62	43.55	49.31	22.57	25.46
	4	1.437	1.376	0.140	26.59	16.02	12.73	44.26	46.72	19.17	26.04

FIGURE 5.25 PROJECTED VALUES OF QUARTERLY ENDOGENOUS VARIABLES IN THE LIVESTOCK MEAT ECONOMY, UNITED STATES, THIRD QUARTER 1966 TO FOURTH QUARTER 1969

YEAR AND QUARTER	SFP	HP	BRF	HEQ	STQ	SHQ	COQ	HQ	SQ	CAAW
1966 3	28.54	24.45	14.79	1845.	4609.	6454.	1604.	13958.	1772.	990.
4	29.47	21.09	12.34	1887.	4225.	6112.	1849.	18555.	1584.	989.
1967 1	30.21	22.08	12.75	1603.	4204.	5807.	1079.	18869.	1387.	1036.
2	31.73	19.43	12.11	1643.	4685.	6327.	738.	19897.	1589.	1043.
3	31.23	19.16	13.01	1712.	4807.	6520.	1125.	15989.	2451.	1012.
4	31.61	16.86	10.79	1854.	4437.	6291.	1531.	20874.	1989.	1011.
1968 1	31.14	18.77	11.62	1688.	4465.	6154.	902.	20953.	1401.	1060.
2	31.42	18.57	11.58	1774.	4958.	6731.	593.	20910.	1388.	1067.
3	29.66	20.17	12.76	1838.	5156.	6994.	1052.	15648.	2154.	1032.
4	28.96	18.65	10.53	2042.	4697.	6739.	1550.	19934.	1833.	1025.
1969 1	28.05	20.10	11.15	1882.	4669.	6551.	931.	20425.	1260.	1073.
2	28.17	19.51	11.10	1946.	5143.	7089.	615.	20962.	1172.	1080.
3	26.25	21.24	12.20	2020.	5341.	7361.	1245.	15427.	2048.	1042.
4	25.34	19.56	9.76	2231.	4885.	7115.	1791.	19586.	1806.	1032.

FIGURE 5.25 (CONTINUED)

YEAR AND QUARTER	ZAW	CY	BQ	PQ	CAQ	ZAQ	BRGP	BTN	SFQ	BRQ
1966 3	244.8	57.9	4648.	2408.	8184.	15826.	4.95	1.388	3113.	2523.
4	242.0	57.2	4530.	3020.	8063.	20209.	4.98	1.148	2816.	2308.
1967 1	247.9	58.0	4130.	3088.	6945.	20345.	5.10	0.915	2646.	2208.
2	250.5	58.8	4323.	3295.	7133.	21699.	5.15	0.934	4460.	2417.
3	251.4	58.5	4537.	2845.	7741.	18581.	5.14	1.274	3321.	2572.
4	245.1	57.7	4575.	3430.	7908.	22960.	4.99	1.071	2731.	2371.
1968 1	247.8	58.3	4347.	3381.	7099.	22458.	4.90	0.893	2389.	2239.
2	248.0	59.0	4597.	3369.	7379.	22418.	4.89	0.944	4238.	2446.
3	249.5	58.7	4884.	2744.	8133.	17943.	4.87	1.321	3324.	2628.
4	244.6	57.9	4926.	3284.	8371.	21862.	4.82	1.128	2691.	2458.
1969 1	248.5	58.4	4671.	3311.	7521.	21787.	4.81	0.945	2237.	2346.
2	248.7	59.1	4899.	3370.	7754.	22254.	4.83	0.999	4193.	2557.
3	250.4	58.6	5265.	2723.	8698.	17615.	4.81	1.407	3370.	2747.
4	245.7	57.8	5324.	3263.	8995.	21486.	4.75	1.197	2760.	2580.

FIGURE 5.25 (CONTINUED)

Simulation of Alternative Historical Livestock-Meat Economies

A major purpose of constructing the simulation model of the livestock-meat industry was to determine the influence of alternative levels of corn price on the net returns of certain classes of livestock producers. The first step in ascertaining this influence was to supply the simulation model with different time series of corn prices and observe the generated estimates of the endogenous variables. The resulting prices of livestock, together with the assumed and historical corn prices, were then used in conjunction with the predicted historical configurations of livestock prices to estimate the change in net returns.

Alternative historical corn prices

Beginning in the fourth quarter of 1956, except for seasonal fluctuations, corn price underwent a downward trend until the first quarter of 1962. Since then an upward trend has been observed. Three alternative sets of corn prices were examined on the assumption that past farm programs might have been implemented in such a manner that these structures were generated rather than what was historically experienced.

The first alternative corn price structure was constructed on the assumption that the downward trend of the late 1950's and early 1960's continued through 1964 with the same seasonal pattern. The following equation was estimated by least squares regression from fourth quarter 1956 through third quarter 1961 data.

$$CP_t = 1.660 - \underset{(7.89)}{.014T_t} + \underset{(0.41)}{.012D4_t} + \underset{(3.97)}{.115D3_t} + \underset{(2.50)}{.072D2_t}$$

$$S = .045 \qquad R^2 = .829 \qquad \rho = 0 \qquad d = 0.97 \qquad (5.3)$$

Corn prices for the remainder of 1961 and through 1964 were then estimated by applying the estimated coefficients to the trend and seasonal variables of this period.

The second alternative set of corn prices is based on the assumption that farm policy was implemented in the fourth quarter of 1957 to keep corn prices at about \$1.25 per bushel except for seasonal changes. This structure of prices was generated by the equation:

$$CP_t = 1.25 + .012D4_t + .115D3_t + .072D2_t \qquad (5.4)$$

The final alternative set of corn prices reflects hypothetical policy action which allowed the upward trend which began in the fourth quarter of 1961, to have instead started in the first quarter of 1957 and to have carried through to the end of 1964. Least squares regression was applied to data from the fourth quarter of 1961 to the fourth quarter of 1964 to yield the following equation:

$$CP_t = .446 + \underset{(3.98)}{.014T_t} - \underset{(-0.09)}{.003D4_t} + \underset{(1.25)}{.048D3_t} + \underset{(0.85)}{.032D2_t}$$

$$S = .046 \qquad R^2 = .725 \qquad \rho = 0 \qquad d = 0.89 \qquad (5.5)$$

The hypothetical structure of prices was then constructed using the trend component of Equation 5.5 and the estimated seasonal structure of Equation 5.3. Hence,

$$CP_t = .945 + .014T_t + .012D4_t + .115D3_t + .072D2_t \qquad (5.6)$$

The three hypothetical sets of corn prices together with the historical prices are listed in Table 5.4 and graphically demonstrated in Figure 5.26.

The alternative historical corn price structures were supplied to the simulation model as exogenous data in three separate trials. The simulation was started on the basis of 1953 initial conditions as in the verification of the model. Hence, up to the period where the alternative corn prices were introduced, the simulated values of all endogenous variables are the same as described in Table 5.1 and Figure 5.1 and graphically depicted in Figures 5.2 to 5.23. Beginning in this period, any differences from the previously simulated values of the endogenous variables are due solely to the different corn prices.

The simulated values of the endogenous variables for each of the alternative livestock-meat economies are given in Figures 5.27 to 5.29 and Tables 5.5 to 5.7. The farm level prices are graphically compared with the relevant historically simulated price structure for each alternative set of corn prices in Figures 5.30 to 5.41.

In general, livestock prices changed in the same direction from their predicted historical levels as the hypothetical corn price changed from its actual historical value. One exception can be noted for hog prices generated under "Strategy-3" (Figure 5.40). In the initial period of increased corn price, the hog price declines from its previous level. This is attributable to the greater marketings of breeding herds (sows) in response to the higher anticipated

Table 5.4 Actual and hypothetical prices for No. 3 yellow corn Chicago

Year and quarter		Actual	Alternative price structure Number one	Number two	Number three
		------------------ $ per bushel ------------------			
1953	2	1.578	1.578	1.578	1.578
	3	1.576	1.576	1.576	1.576
	4	1.522	1.522	1.522	1.522
1954	1	1.556	1.556	1.556	1.556
	2	1.572	1.572	1.572	1.572
	3	1.625	1.625	1.625	1.625
	4	1.553	1.553	1.553	1.553
1955	1	1.514	1.514	1.514	1.514
	2	1.468	1.468	1.468	1.468
	3	1.417	1.417	1.417	1.417
	4	1.223	1.223	1.223	1.223
1956	1	1.251	1.251	1.251	1.251
	2	1.432	1.432	1.432	1.432
	3	1.542	1.542	1.542	1.542
	4	1.398	1.398	1.398	1.398
1957	1	1.325	1.325	1.325	1.317
	2	1.307	1.307	1.307	1.403
	3	1.322	1.322	1.322	1.459
	4	1.203	1.203	1.262	1.370
1958	1	1.128	1.128	1.250	1.372
	2	1.255	1.255	1.322	1.458
	3	1.345	1.345	1.365	1.514
	4	1.177	1.177	1.262	1.425

Table 5.4 (Continued)

Year and quarter		Actual	Alternative price structure Number one	Number two	Number three
		$ per bushel			
1959	1	1.172	1.172	1.250	1.427
	2	1.260	1.260	1.322	1.513
	3	1.275	1.275	1.365	1.569
	4	1.120	1.120	1.262	1.480
1960	1	1.122	1.122	1.250	1.482
	2	1.189	1.189	1.322	1.568
	3	1.193	1.193	1.365	1.625
	4	1.061	1.061	1.262	1.536
1961	1	1.082	1.082	1.250	1.537
	2	1.106	1.106	1.322	1.623
	3	1.126	1.126	1.365	1.680
	4	1.098	1.100	1.262	1.591
1962	1	1.078	1.074	1.250	1.593
	2	1.124	1.131	1.322	1.678
	3	1.117	1.160	1.365	1.735
	4	1.095	1.043	1.262	1.646
1963	1	1.166	1.017	1.250	1.648
	2	1.215	1.075	1.322	1.733
	3	1.310	1.104	1.365	1.790
	4	1.227	.987	1.262	1.701
1964	1	1.200	.961	1.250	1.703
	2	1.242	1.018	1.322	1.788
	3	1.243	1.047	1.365	1.845
	4	1.214	.930	1.262	1.756

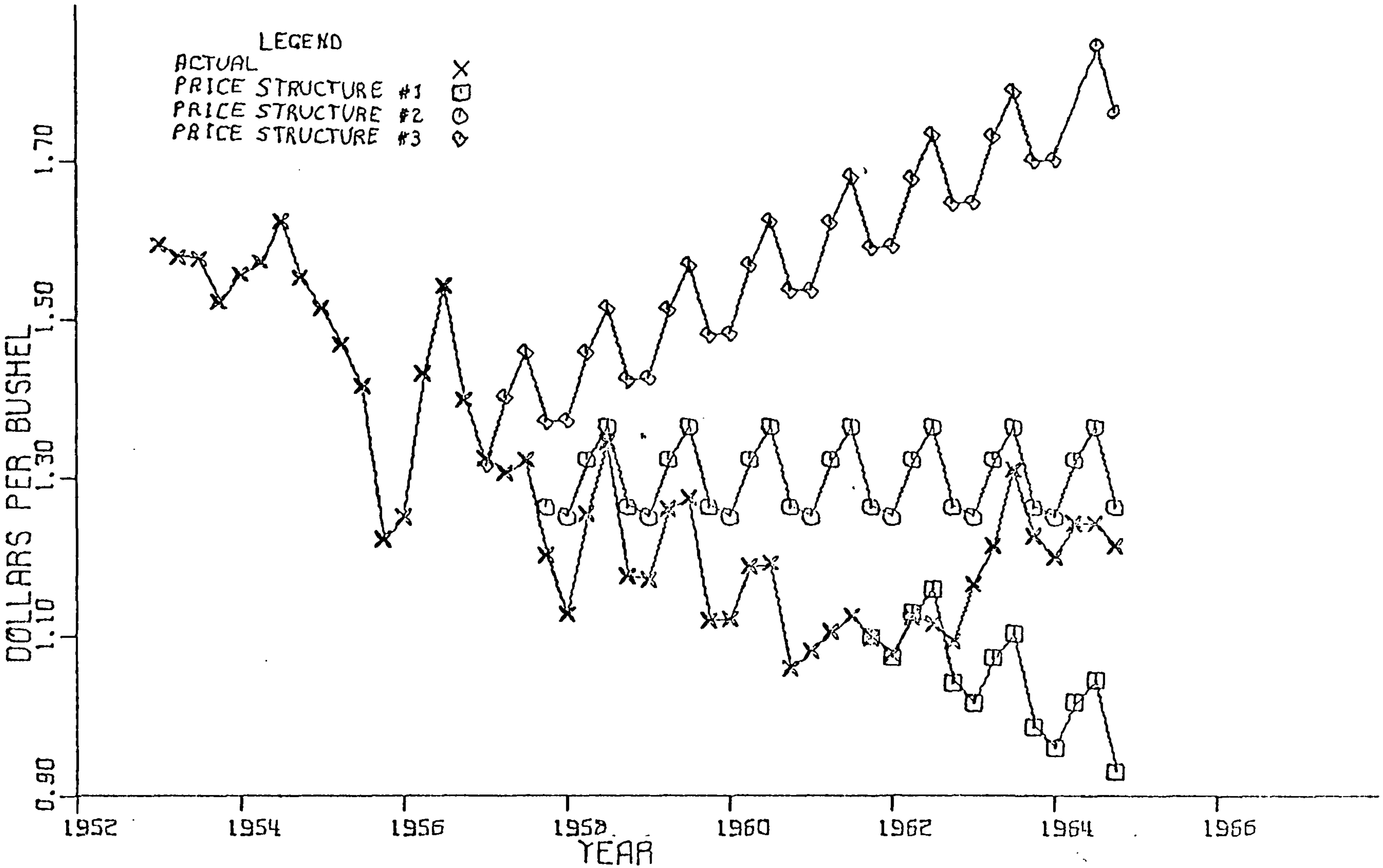

FIGURE 5.26 ACTUAL AND HYPOTHETICAL PRICES NUMBER 3 YELLOW CORN CHICAGO

Table 5.5 Simulated annual endogenous variables in alternative livestock-meat economy based on hypothetical corn price structure number one

Year	CBS	CVS	STS	HES	SHS
1962	28,748	21,978	11,065	7,520	18,585
1963	30,043	23,131	11,541	7,885	19,426
1964	31,429	24,183	12,060	8,234	20,294

Table 5.6 Simulated annual endogenous variables in alternative livestock-meat economy based on hypothetical corn price structure number two

Year	CBS	CVS	STS	HES	SHS
1958	24,183	18,768	9,143	6,248	15,391
1959	24,851	19,490	10,268	6,801	17,069
1960	26,167	19,997	10,795	7,308	18,103
1961	27,541	20,939	10,766	7,444	18,211
1962	28,842	22,067	11,067	7,695	18,762
1963	30,170	23,217	11,541	8,067	19,609
1964	31,576	24,298	12,038	8,454	20,492

Table 5.7 Simulated annual endogenous variables in alternative livestock-meat economy based on hypothetical corn price structure number three

Year	CBS	CVS	STS	HES	SHS
1957	24,283	18,468	8,924	6,266	15,190
1958	24,189	18,786	9,131	6,313	15,444
1959	24,890	19,533	10,285	6,930	17,215
1960	26,256	20,058	10,803	7,489	18,292
1961	27,670	21,032	10,751	7,665	18,416
1962	29,007	22,196	11,049	7,963	19,013
1963	30,373	23,379	11,530	8,389	19,919
1964	31,822	24,493	12,028	8,827	20,855

costs of feeding market hogs. Once the liquidation of sows is completed, price then returns to its previous level. The smaller number of hogs marketed as a consequence of the reduced farrowings eventually leads to higher hog prices than had existed under the historical configuration of corn prices.

Changes in net returns

On the basis of the simulated results for the alternative structures of corn prices, it is clear that farm policy which creates higher feed grain prices will also lead to higher livestock prices (and conversely for lower feed grain prices). It is not immediately obvious, however, whether livestock producers receive a net income gain since the increased cost of feed may offset the increased gross return.

YEAR AND QUARTER		BSN	PSN	BRSN	BCN	PCN	BRCN	BPW	PPW	BRP	SP
1961	4	1.072	0.993	0.141	21.87	15.36	8.74	43.82	42.57	25.62	26.43
1962	1	1.043	1.518	0.123	21.16	15.20	8.28	42.87	41.62	26.61	25.46
	2	0.953	1.894	0.114	21.88	15.08	9.46	41.85	41.48	26.49	25.30
	3	0.920	0.985	0.120	23.06	13.72	10.47	42.15	45.02	26.84	25.14
	4	1.129	1.122	0.143	22.58	15.53	9.26	44.18	42.91	24.40	26.61
1963	1	1.070	1.574	0.120	21.82	15.16	8.72	42.50	42.00	25.73	25.13
	2	1.008	1.965	0.111	22.78	15.07	9.91	40.41	40.11	25.49	24.25
	3	1.011	1.094	0.119	24.19	13.80	10.89	40.94	45.06	25.77	24.23
	4	1.222	1.209	0.143	23.74	15.58	9.67	42.12	42.08	23.59	25.12
1964	1	1.137	1.630	0.122	22.88	15.12	9.16	40.82	42.44	25.13	23.89
	2	1.060	2.024	0.114	23.70	15.30	10.39	38.86	39.93	24.89	23.09
	3	1.070	1.144	0.119	25.15	13.87	11.39	39.23	44.34	25.45	22.97
	4	1.277	1.228	0.143	24.75	15.76	10.29	40.41	41.02	22.74	23.86

FIGURE 5.27 SIMULATED QUARTERLY ENDOGENOUS VARIABLES IN ALTERNATIVE LIVESTOCK-MEAT ECONOMY BASED ON HYPOTHETICAL CORN PRICE STRUCTURE NUMBER ONE

YEAR AND QUARTER		SFP	HP	BRF	HEQ	STQ	SHQ	COQ	HQ	SQ	CAAW
1961	4	26.60	17.20	14.84	1561.	3471.	5032.	1762.	19114.	1557.	996.
1962	1	26.25	16.95	15.51	1450.	3411.	4861.	1394.	19283.	1214.	1029.
	2	27.02	17.06	15.41	1437.	3809.	5246.	1139.	18910.	1315.	1025.
	3	26.21	18.76	15.66	1491.	3933.	5424.	1466.	14321.	2301.	1000.
	4	26.58	17.38	13.92	1631.	3575.	5206.	1847.	19258.	1595.	1001.
1963	1	26.35	17.16	14.84	1497.	3588.	5085.	1356.	19397.	1188.	1038.
	2	26.66	16.19	14.64	1535.	4020.	5555.	1085.	19301.	1254.	1036.
	3	25.19	18.77	14.84	1578.	4188.	5766.	1483.	14766.	2251.	1008.
	4	24.87	16.85	13.28	1740.	3804.	5544.	1904.	19504.	1637.	1007.
1964	1	24.18	17.41	14.33	1630.	3783.	5413.	1363.	19869.	1163.	1047.
	2	24.28	16.06	14.15	1661.	4222.	5883.	1094.	19791.	1244.	1046.
	3	22.56	18.30	14.55	1703.	4403.	6107.	1605.	15160.	2138.	1015.
	4	22.16	16.17	12.61	1875.	4002.	5877.	2063.	19754.	1	1012.

FIGURE 5.27 (CONTINUED)

YEAR AND QUARTER		ZAW	CY	BQ	PQ	CAQ	ZAQ	BRGP	BTN	SFQ	BRQ
1961	4	233.0	57.1	3876.	2868.	6888.	20762.	4.66	1.369	2689.	1596.
1962	1	238.3	57.4	3696.	2899.	6320.	20596.	4.67	1.342	2480.	1509.
	2	238.6	58.2	3813.	2860.	6462.	20339.	4.70	1.478	4499.	1731.
	3	241.4	57.9	4010.	2391.	6994.	16758.	4.70	1.760	3136.	1927.
	4	234.8	57.1	4044.	2932.	7146.	20944.	4.62	1.409	2731.	1716.
1963	1	239.0	57.6	3847.	2936.	6497.	20684.	4.61	1.515	2471.	1614.
	2	239.1	58.4	4016.	2928.	6710.	20670.	4.63	1.653	4508.	1843.
	3	241.4	58.1	4260.	2461.	7348.	17155.	4.63	1.842	3212.	2034.
	4	235.5	57.2	4306.	2996.	7539.	21233.	4.55	1.457	2761.	1817.
1964	1	239.3	57.7	4088.	3017.	6828.	21132.	4.54	1.598	2496.	1721.
	2	239.8	58.5	4263.	3017.	7044.	21151.	4.56	1.738	4439.	1960.
	3	241.4	58.1	4561.	2517.	7812.	17437.	4.56	1.808	3314.	2159.
	4	236.1	57.2	4611.	3058.	8034.	21523.	4.49	1.389	2777.	1962.

FIGURE 5.27 (CONTINUED)

YEAR AND QUARTER		BSN	PSN	BRSN	BCN	PCN	BRCN	BPW	PPW	BRP	SP
1957	4	0.805	0.750	0.133	20.33	14.48	6.96	43.01	45.89	29.75	26.23
1958	1	0.763	1.346	0.124	19.18	14.32	6.57	43.70	46.03	30.38	26.35
	2	0.600	1.518	0.113	19.13	13.71	7.86	45.24	48.85	30.79	27.94
	3	0.600	0.750	0.128	19.73	12.80	9.11	45.50	50.87	30.20	27.74
	4	0.857	0.989	0.155	19.23	14.97	7.74	46.48	45.25	28.07	28.49
1959	1	0.892	1.677	0.134	18.39	15.06	7.24	45.79	42.90	29.07	27.68
	2	0.878	1.944	0.114	19.48	14.73	8.46	42.38	42.36	28.68	25.91
	3	0.838	1.021	0.121	20.54	14.10	9.42	42.34	44.49	28.04	25.51
	4	1.065	1.245	0.144	20.12	16.01	7.84	44.88	40.96	26.70	27.32
1960	1	1.068	1.835	0.122	19.46	15.91	7.31	44.40	39.19	28.25	26.65
	2	0.962	2.014	0.106	20.36	15.37	8.53	42.52	39.73	28.25	25.91
	3	0.882	0.952	0.113	21.47	14.27	9.55	42.24	42.32	28.20	25.34
	4	1.081	1.091	0.139	21.05	15.89	8.17	44.46	40.43	26.36	26.94
1961	1	1.066	1.624	0.119	20.47	15.37	7.65	44.40	41.52	27.54	26.57
	2	0.905	1.854	0.106	20.87	14.95	8.82	43.29	41.14	28.07	26.36
	3	0.833	0.849	0.114	22.03	13.53	9.96	42.83	44.83	28.29	25.67
	4	1.059	0.990	0.141	21.49	15.12	8.75	44.76	43.35	26.19	27.07
1962	1	1.038	1.499	0.122	20.90	14.76	8.32	43.37	43.03	27.17	25.79
	2	0.953	1.866	0.113	21.63	14.60	9.52	42.24	43.06	27.02	25.57
	3	0.921	0.957	0.119	22.81	13.21	10.54	42.53	46.72	27.38	25.39
	4	1.130	1.108	0.144	22.32	15.05	9.34	44.68	44.49	24.91	26.94
1963	1	1.068	1.580	0.122	21.50	14.75	8.80	43.22	43.32	26.23	25.61
	2	1.001	1.972	0.113	22.45	14.65	9.99	41.12	41.48	26.01	24.72
	3	1.004	1.102	0.120	23.83	13.40	10.97	41.73	46.39	26.31	24.76
	4	1.218	1.243	0.144	23.36	15.22	9.74	43.05	43.22	24.13	25.74
1964	1	1.131	1.692	0.122	22.46	14.82	9.22	41.88	43.38	25.67	24.61
	2	1.046	2.058	0.113	23.27	14.92	10.43	39.84	41.15	25.55	23.76
	3	1.055	1.154	0.118	24.68	13.47	11.43	40.30	45.62	26.15	23.70
	4	1.265	1.254	0.142	24.26	15.36	10.33	41.60	42.31	23.49	24.67

FIGURE 5.28 SIMULATED QUARTERLY ENDOGENOUS VARIABLES IN ALTERNATIVE LIVESTOCK-MEAT ECONOMY BASED ON HYPOTHETICAL CORN PRICE STRUCTURE NUMBER TWO

YEAR AND QUARTER		SFP	HP	BRF	HEQ	STQ	SHQ	COQ	HQ	SQ	CAAW
1957	4	25.13	19.32	18.01	1100.	3148.	4248.	2303.	17342.	1305.	956.
1958	1	27.18	19.75	18.43	1011.	3107.	4118.	1701.	17691.	1184.	989.
	2	30.57	21.68	18.71	983.	3304.	4287.	1410.	16222.	1299.	981.
	3	31.08	22.45	18.29	1045.	3326.	4371.	1483.	12297.	2663.	965.
	4	32.21	18.90	16.76	1176.	3010.	4185.	1704.	18039.	1460.	974.
1959	1	32.33	17.80	17.44	1052.	3005.	4057.	1338.	18665.	1300.	1003.
	2	32.48	17.67	17.15	1135.	3445.	4580.	1103.	17652.	1475.	997.
	3	30.73	18.50	16.69	1138.	3610.	4748.	1147.	13814.	2798.	981.
	4	30.67	16.25	15.72	1252.	3288.	4540.	1507.	19463.	1709.	985.
1960	1	29.90	15.49	16.79	1152.	3247.	4399.	1302.	19820.	1393.	1012.
	2	30.05	16.03	16.77	1225.	3594.	4819.	1083.	18610.	1510.	1005.
	3	28.39	17.14	16.73	1231.	3782.	5014.	1226.	14136.	2644.	986.
	4	28.02	15.90	15.42	1351.	3449.	4800.	1614.	19299.	1689.	989.
1961	1	27.76	16.91	16.23	1276.	3403.	4679.	1365.	19287.	1320.	1018.
	2	28.47	16.88	16.60	1259.	3697.	4956.	1118.	18279.	1380.	1012.
	3	26.93	18.67	16.75	1282.	3857.	5140.	1358.	13636.	2384.	990.
	4	26.85	17.67	15.24	1416.	3531.	4947.	1753.	18451.	1616.	991.
1962	1	26.44	17.82	15.91	1320.	3492.	4812.	1386.	18519.	1199.	1024.
	2	27.12	18.03	15.79	1324.	3880.	5204.	1132.	18086.	1286.	1021.
	3	26.22	19.81	16.05	1347.	4036.	5383.	1461.	13401.	2321.	995.
	4	26.54	18.35	14.28	1475.	3688.	5163.	1847.	18347.	1607.	995.
1963	1	26.31	17.97	15.19	1371.	3650.	5021.	1358.	18611.	1197.	1032.
	2	26.62	17.04	15.01	1399.	4089.	5488.	1086.	18450.	1267.	1030.
	3	25.16	19.59	15.23	1428.	4267.	5696.	1490.	13851.	2341.	1001.
	4	24.87	17.55	13.66	1583.	3890.	5473.	1913.	18686.	1682.	1000.
1964	1	24.23	17.98	14.72	1459.	3869.	5327.	1366.	19143.	1207.	1039.
	2	24.35	16.81	14.61	1487.	4308.	5795.	1094.	18870.	1284.	1038.
	3	22.65	19.09	15.04	1516.	4500.	6016.	1609.	14141.	2253.	1006.
	4	22.28	16.96	13.14	1681.	4104.	5785.	2067.	18792.	1724.	1003.

FIGURE 5.28 (CONTINUED)

YEAR AND QUARTER		ZAW	CY	BQ	PQ	CAQ	ZAQ	BRGP	BTN	SFQ	BRQ
1957	4	230.7	55.4	3516.	2510.	6697.	18731.	4.88	0.365	2587.	1189.
1958	1	235.9	56.2	3264.	2586.	5923.	18968.	4.89	0.558	2343.	1121.
	2	236.9	57.1	3218.	2412.	5812.	17625.	4.93	0.742	4815.	1347.
	3	242.8	57.2	3266.	2111.	5982.	15090.	4.94	1.355	2907.	1575.
	4	233.0	56.5	3264.	2665.	5998.	19586.	4.88	1.145	2763.	1347.
1959	1	237.2	56.9	3092.	2763.	5474.	20062.	4.89	1.087	2548.	1255.
	2	237.6	57.9	3290.	2651.	5776.	19236.	4.93	1.201	4927.	1474.
	3	241.9	58.0	3373.	2344.	6000.	16748.	4.94	1.766	3086.	1653.
	4	233.3	57.1	3418.	2903.	6140.	21265.	4.88	1.409	2750.	1386.
1960	1	237.5	57.2	3310.	2950.	5772.	21314.	4.89	1.207	2509.	1289.
	2	238.0	58.0	3453.	2805.	5988.	20232.	4.93	1.312	4671.	1513.
	3	241.8	58.0	3589.	2383.	6343.	16917.	4.94	1.790	3011.	1704.
	4	234.1	57.1	3639.	2906.	6507.	21080.	4.88	1.409	2618.	1469.
1961	1	238.6	57.3	3533.	2899.	6113.	20706.	4.89	1.255	2335.	1373.
	2	239.4	58.1	3578.	2777.	6156.	19771.	4.93	1.398	4404.	1591.
	3	242.7	57.9	3745.	2306.	6601.	16154.	4.94	1.777	2946.	1807.
	4	235.8	57.0	3804.	2824.	6794.	20156.	4.88	1.393	2518.	1599.
1962	1	240.2	57.4	3646.	2817.	6262.	19814.	4.89	1.367	2279.	1515.
	2	240.7	58.2	3765.	2771.	6413.	19482.	4.93	1.493	4354.	1742.
	3	244.3	57.9	3962.	2298.	6948.	15855.	4.94	1.772	2970.	1940.
	4	237.4	57.1	3995.	2846.	7102.	20043.	4.88	1.415	2552.	1731.
1963	1	241.7	57.6	3786.	2864.	6436.	19904.	4.89	1.521	2278.	1629.
	2	241.9	58.4	3950.	2849.	6644.	19828.	4.93	1.663	4389.	1857.
	3	245.0	58.0	4192.	2386.	7285.	16327.	4.94	1.846	3026.	2048.
	4	238.7	57.2	4235.	2933.	7477.	20458.	4.88	1.461	2560.	1830.
1964	1	242.6	57.7	4006.	2965.	6745.	20449.	4.89	1.611	2272.	1732.
	2	243.1	58.5	4176.	2940.	6955.	20268.	4.93	1.755	4284.	1968.
	3	245.6	58.0	4469.	2437.	7726.	16529.	4.94	1.819	3071.	2167.
	4	239.9	57.1	4516.	2985.	7947.	20606.	4.88	1.402	2521.	1970.

FIGURE 5.28 (CONTINUED)

YEAR AND QUARTER	BSN	PSN	BRSN	BCN	PCN	BRCN	BPW	PPW	BRP	SP
1957 1	0.848	2.280	0.131	20.01	15.67	5.57	38.94	39.10	31.00	23.24
2	0.606	2.001	0.100	20.07	14.37	6.83	39.99	43.83	32.00	24.49
3	0.600	0.750	0.106	20.63	13.02	8.19	42.32	48.68	31.94	25.68
4	0.797	0.774	0.136	19.99	14.68	6.94	44.12	45.16	29.95	26.98
1958 1	0.754	1.378	0.125	18.88	14.47	6.54	44.64	45.48	30.59	26.99
2	0.600	1.532	0.111	18.85	13.79	7.82	46.02	48.51	31.04	28.47
3	0.600	0.750	0.124	19.45	12.71	9.07	46.14	51.15	30.63	28.18
4	0.850	0.963	0.151	18.92	14.84	7.72	47.23	45.63	28.51	29.00
1959 1	0.879	1.655	0.132	18.03	14.87	7.23	46.72	43.45	29.60	28.31
2	0.868	1.919	0.114	19.16	14.51	8.47	43.08	43.05	29.12	26.38
3	0.825	0.983	0.120	20.21	13.78	9.43	42.96	45.58	28.59	25.93
4	1.053	1.215	0.144	19.77	15.66	7.88	45.61	42.08	27.25	27.81
1960 1	1.057	1.819	0.123	19.09	15.54	7.35	45.28	40.36	28.85	27.24
2	0.953	2.004	0.106	19.99	14.99	8.59	43.31	40.97	28.80	26.44
3	0.872	0.939	0.112	21.08	13.85	9.60	43.02	43.71	28.82	25.87
4	1.075	1.101	0.139	20.66	15.49	8.23	45.38	41.73	26.97	27.56
1961 1	1.058	1.653	0.119	20.04	14.97	7.71	45.45	42.82	28.20	27.28
2	0.893	1.870	0.105	20.43	14.49	8.89	44.25	42.62	28.75	27.01
3	0.821	0.850	0.113	21.57	13.05	10.02	43.82	46.42	29.02	26.34
1961 4	1.051	1.013	0.141	21.03	14.65	8.82	45.87	44.87	26.92	27.82
1962 1	1.027	1.544	0.122	20.38	14.28	8.39	44.61	44.57	27.96	26.63
2	0.938	1.888	0.112	21.12	14.03	9.59	43.31	44.91	27.84	26.30
3	0.906	0.958	0.117	22.29	12.62	10.62	43.64	48.69	28.25	26.15
4	1.122	1.135	0.143	21.79	14.47	9.42	45.92	46.39	25.79	27.78
1963 1	1.058	1.639	0.122	20.92	14.16	8.89	44.58	45.21	27.15	26.53
2	0.985	1.999	0.112	21.88	13.94	10.08	42.27	43.80	26.98	25.50
3	0.991	1.109	0.118	23.24	12.68	11.07	42.94	48.76	27.30	25.58
4	1.211	1.281	0.144	22.78	14.52	9.84	44.39	45.50	25.13	26.65
1964 1	1.123	1.769	0.123	21.83	14.14	9.32	43.35	45.58	26.69	25.60
2	1.029	2.094	0.112	22.64	14.08	10.53	41.09	43.88	26.67	24.61
3	1.041	1.167	0.116	24.03	12.65	11.55	41.63	48.36	27.26	24.60
4	1.259	1.301	0.142	23.61	14.55	10.45	43.07	44.94	24.62	25.66

FIGURE 5.29 SIMULATED QUARTERLY ENDOGENOUS VARIABLES IN ALTERNATIVE LIVESTOCK-MEAT ECONOMY BASED ON HYPOTHETICAL CORN PRICE STRUCTURE NUMBER THREE

YEAR AND QUARTER		SFP	HP	BRF	HEQ	STQ	SHQ	COQ	HQ	SQ	CAAW
1957	1	18.82	15.51	18.94	1091.	3142.	4234.	2016.	18971.	1376.	976.
	2	21.33	18.62	19.64	1048.	3325.	4372.	1789.	16595.	1306.	964.
	3	23.09	21.13	19.59	979.	3462.	4441.	2089.	11948.	2767.	944.
	4	25.39	18.87	18.15	1031.	3142.	4173.	2301.	17373.	1424.	952.
1958	1	27.53	19.41	18.58	964.	3090.	4054.	1693.	17747.	1235.	986.
	2	30.94	21.48	18.89	949.	3282.	4231.	1399.	16171.	1338.	977.
	3	31.43	22.62	18.59	957.	3360.	4317.	1464.	12004.	2709.	962.
	4	32.56	19.14	17.07	1065.	3059.	4124.	1683.	17608.	1525.	969.
1959	1	32.69	18.14	17.81	947.	3032.	3979.	1326.	18243.	1325.	998.
	2	32.80	18.09	17.46	1032.	3486.	4517.	1089.	17164.	1495.	992.
	3	30.98	19.17	17.08	1020.	3666.	4685.	1127.	13149.	2827.	976.
	4	30.87	16.93	16.11	1123.	3353.	4477.	1491.	18724.	1752.	980.
1960	1	30.08	16.21	17.21	1009.	3315.	4323.	1295.	19087.	1414.	1006.
	2	30.20	16.78	17.16	1082.	3664.	4746.	1075.	17831.	1538.	999.
	3	28.49	18.00	17.17	1075.	3864.	4939.	1218.	13259.	2702.	979.
	4	28.10	16.70	15.85	1186.	3539.	4725.	1609.	18435.	1733.	981.
1961	1	27.86	17.70	16.70	1096.	3495.	4591.	1363.	18437.	1353.	1010.
	2	28.55	17.78	17.08	1076.	3791.	4867.	1114.	17308.	1421.	1004.
	3	27.00	19.65	17.27	1087.	3962.	5049.	1357.	12578.	2472.	981.
1961	4	26.94	18.61	15.76	1213.	3644.	4857.	1755.	17443.	1663.	982.
1962	1	26.56	18.76	16.48	1100.	3606.	4706.	1385.	17523.	1239.	1015.
	2	27.21	19.17	16.38	1102.	4000.	5102.	1129.	16890.	1329.	1011.
	3	26.30	21.02	16.67	1114.	4168.	5282.	1462.	12110.	2429.	984.
	4	26.63	19.52	14.90	1235.	3827.	5062.	1851.	17132.	1648.	984.
1963	1	26.43	19.13	15.84	1113.	3791.	4904.	1358.	17418.	1238.	1021.
	2	26.70	18.46	15.70	1139.	4237.	5376.	1083.	16995.	1306.	1019.
	3	25.21	21.04	15.93	1157.	4429.	5586.	1494.	12305.	2470.	990.
	4	24.92	18.95	14.37	1307.	4058.	5365.	1920.	17256.	1717.	988.
1964	1	24.30	19.34	15.44	1162.	4039.	5201.	1367.	17761.	1249.	1027.
	2	24.37	18.49	15.41	1188.	4485.	5673.	1093.	17165.	1320.	1026.
	3	22.65	20.77	15.83	1207.	4689.	5896.	1617.	12348.	2406.	993.
	4	22.29	18.58	13.94	1369.	4300.	5669.	2080.	17157.	1754.	990.

FIGURE 5.29 (CONTINUED)

YEAR AND QUARTER		ZAW	CY	BQ	PQ	CAQ	ZAQ	BRGP	BTN	SFQ	BRQ
1957	1	235.3	55.7	3436.	2757.	6376.	20445.	5.00	0.090	2199.	932.
	2	234.8	56.5	3393.	2423.	6303.	18006.	5.03	0.242	4724.	1146.
	3	242.1	56.1	3516.	2055.	6695.	14844.	5.05	0.344	2669.	1388.
	4	232.3	55.3	3458.	2548.	6619.	18881.	5.01	0.368	2530.	1185.
1958	1	237.0	56.2	3210.	2613.	5850.	19075.	5.03	0.576	2252.	1116.
	2	238.1	57.1	3169.	2424.	5745.	17612.	5.09	0.764	4721.	1341.
	3	244.5	57.2	3213.	2094.	5908.	14843.	5.12	1.385	2826.	1567.
	4	234.9	56.4	3204.	2638.	5915.	19219.	5.08	1.175	2632.	1344.
1959	1	239.0	56.9	3025.	2732.	5383.	19663.	5.10	1.110	2399.	1254.
	2	239.7	57.8	3230.	2613.	5699.	18767.	5.15	1.229	4778.	1477.
	3	244.6	58.0	3309.	2285.	5916.	16110.	5.18	1.798	2941.	1655.
	4	235.8	57.1	3353.	2844.	6059.	20566.	5.14	1.436	2575.	1392.
1960	1	240.1	57.2	3240.	2888.	5689.	20600.	5.17	1.227	2327.	1296.
	2	240.8	58.0	3383.	2738.	5907.	19479.	5.22	1.334	4512.	1523.
	3	245.4	58.0	3517.	2307.	6259.	16095.	5.25	1.812	2822.	1714.
	4	237.3	57.1	3565.	2838.	6427.	20257.	5.21	1.426	2405.	1479.
1961	1	241.8	57.3	3451.	2829.	6022.	19887.	5.23	1.272	2116.	1384.
	2	242.9	58.1	3495.	2692.	6063.	18836.	5.29	1.419	4227.	1603.
	3	247.2	57.9	3659.	2216.	6510.	15181.	5.32	1.794	2709.	1819.
1961	4	239.7	57.0	3717.	2742.	6705.	19191.	5.28	1.408	2261.	1611.
1962	1	244.1	57.3	3548.	2733.	6155.	18855.	5.30	1.386	2010.	1527.
	2	244.9	58.2	3668.	2662.	6308.	18326.	5.36	1.517	4150.	1755.
	3	249.6	57.9	3863.	2184.	6847.	14668.	5.39	1.789	2677.	1954.
	4	242.0	57.0	3895.	2742.	7005.	18865.	5.35	1.430	2246.	1746.
1963	1	246.2	57.5	3675.	2760.	6318.	18748.	5.37	1.541	1956.	1645.
	2	246.7	58.4	3839.	2711.	6529.	18408.	5.42	1.689	4159.	1873.
	3	251.2	58.0	4081.	2249.	7179.	14905.	5.45	1.861	2679.	2066.
	4	243.9	57.1	4124.	2807.	7376.	19057.	5.42	1.473	2208.	1848.
1964	1	247.8	57.6	3883.	2844.	6621.	19103.	5.44	1.630	1897.	1750.
	2	248.5	58.5	4052.	2774.	6831.	18593.	5.49	1.780	4034.	1986.
	3	252.7	58.0	4346.	2277.	7615.	14884.	5.52	1.830	2670.	2189.
	4	245.8	57.1	4393.	2837.	7844.	18996.	5.48	1.410	2124.	1992.

FIGURE 5.29 (CONTINUED)

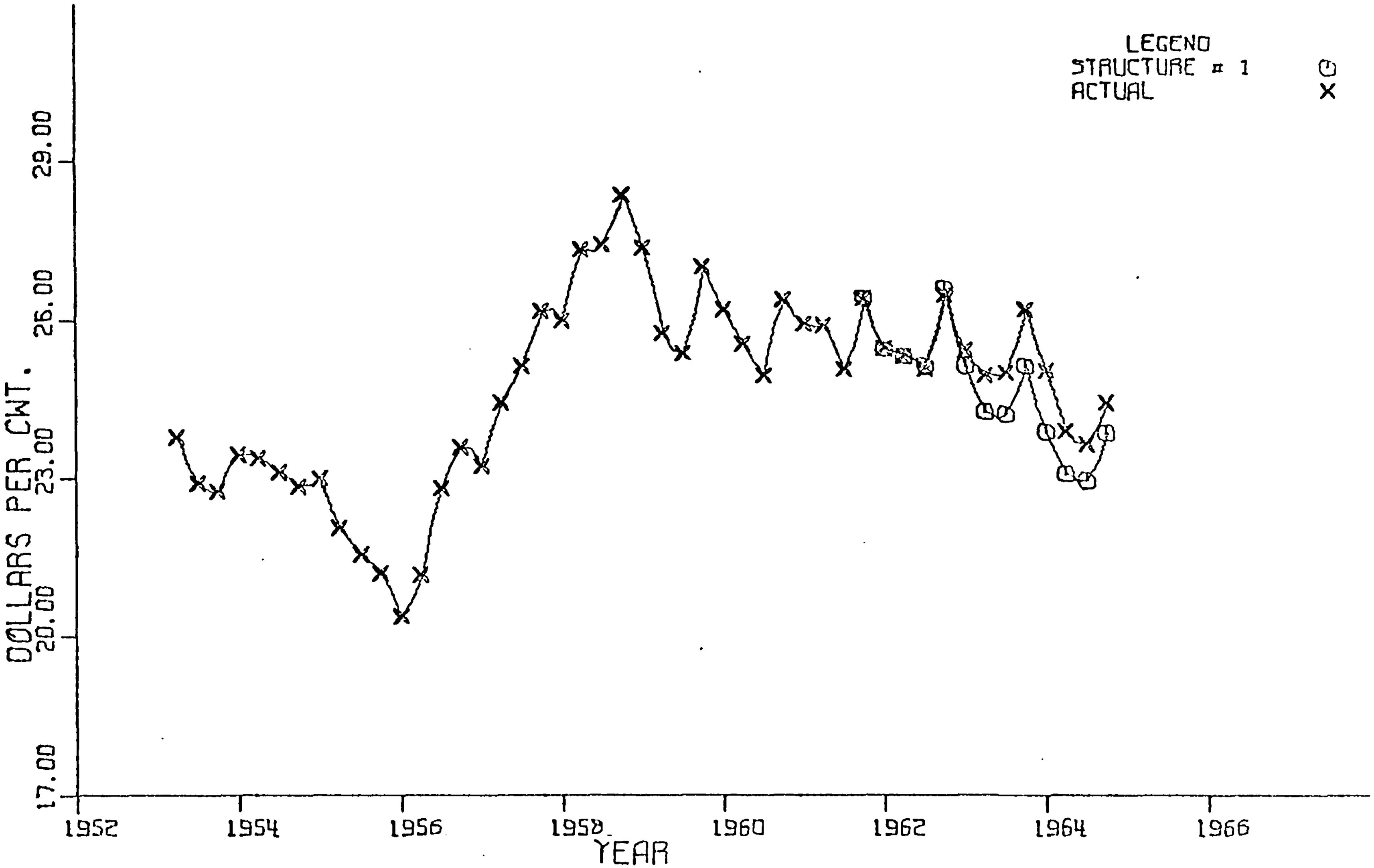

FIGURE 5.30 SIMULATED SLAUGHTER STEER PRICE USING CORN PRICE STRUCTURE NUMBER ONE AND SIMULATED USING ACTUAL CORN PRICE

FIGURE 5.31 SIMULATED FEEDER CALF PRICE USING CORN PRICE STRUCTURE NUMBER ONE AND SIMULATED USING ACTUAL CORN PRICE

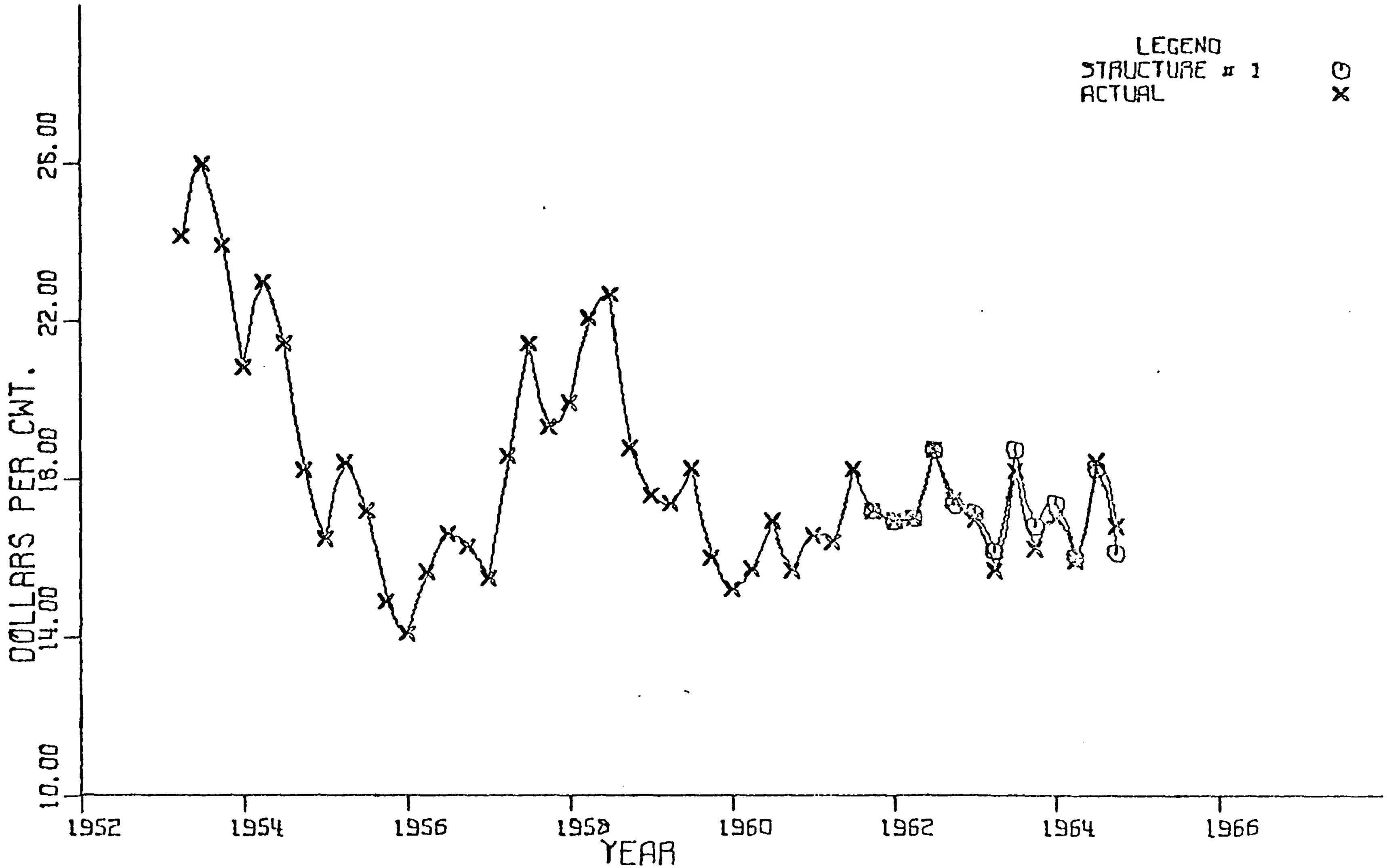

FIGURE 5.32 SIMULATED SLAUGHTER HOG PRICE USING CORN PRICE STRUCTURE NUMBER ONE AND SIMULATED USING ACTUAL CORN PRICE

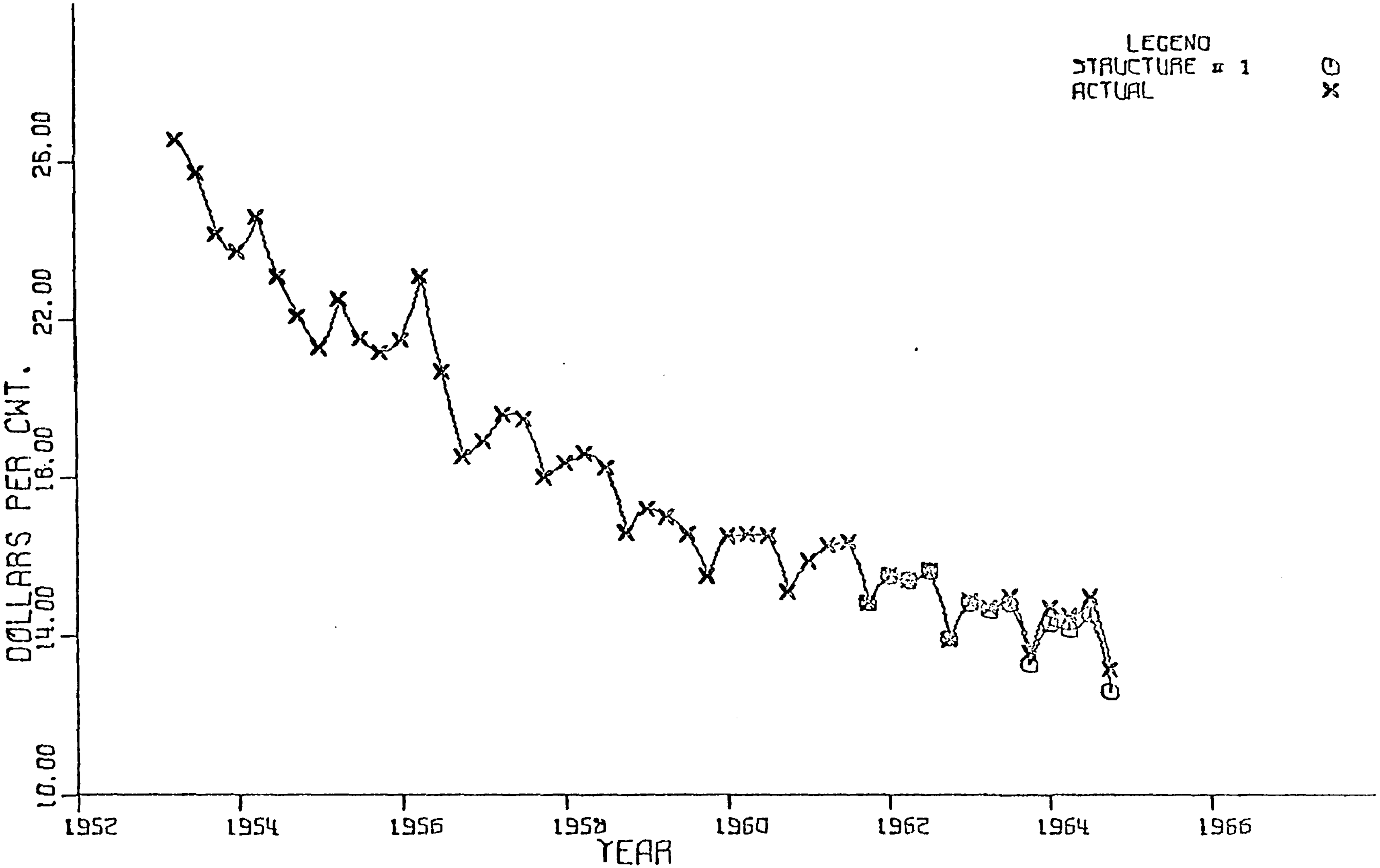

FIGURE 5.33 SIMULATED FARM BROILER PRICE USING CORN PRICE STRUCTURE NUMBER ONE AND SIMULATED USING ACTUAL CORN PRICE

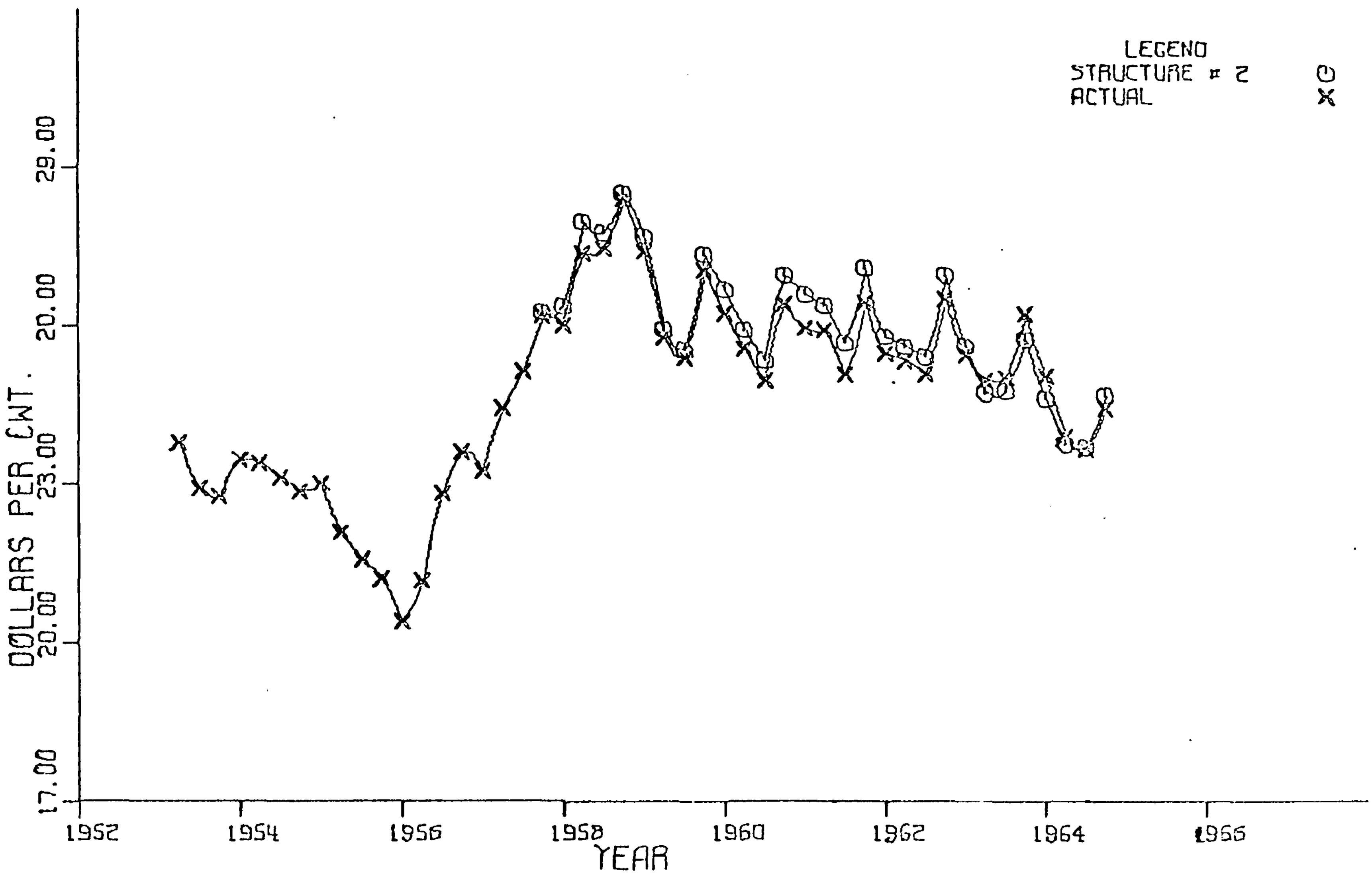

FIGURE 5.34 SIMULATED SLAUGHTER STEER PRICE USING CORN PRICE STRUCTURE NUMBER TWO AND SIMULATED USING ACTUAL CORN PRICE

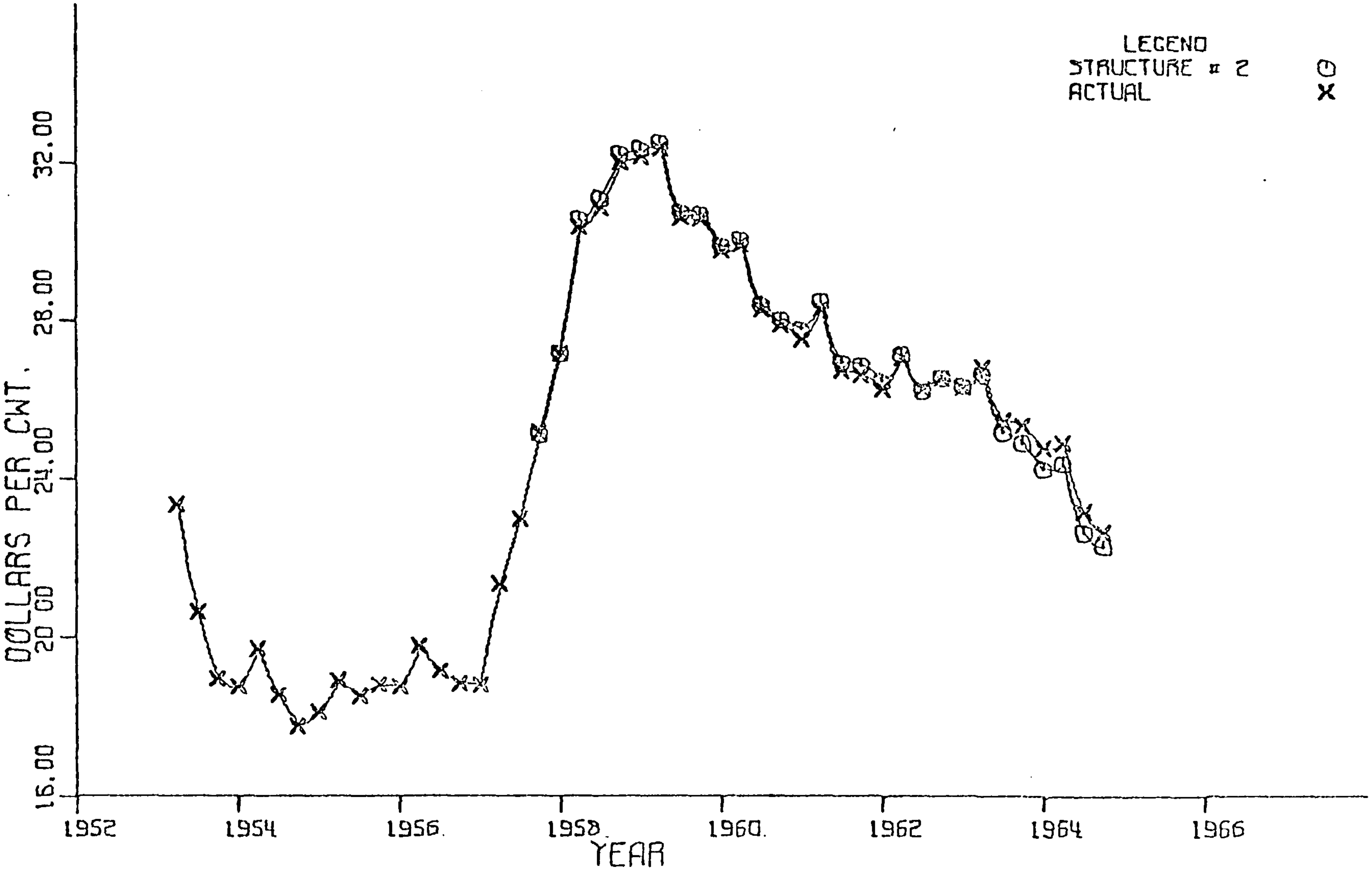

FIGURE 5.35 SIMULATED FEEDER CALF PRICE USING CORN PRICE STRUCTURE NUMBER TWO AND SIMULATED USING ACTUAL CORN PRICE

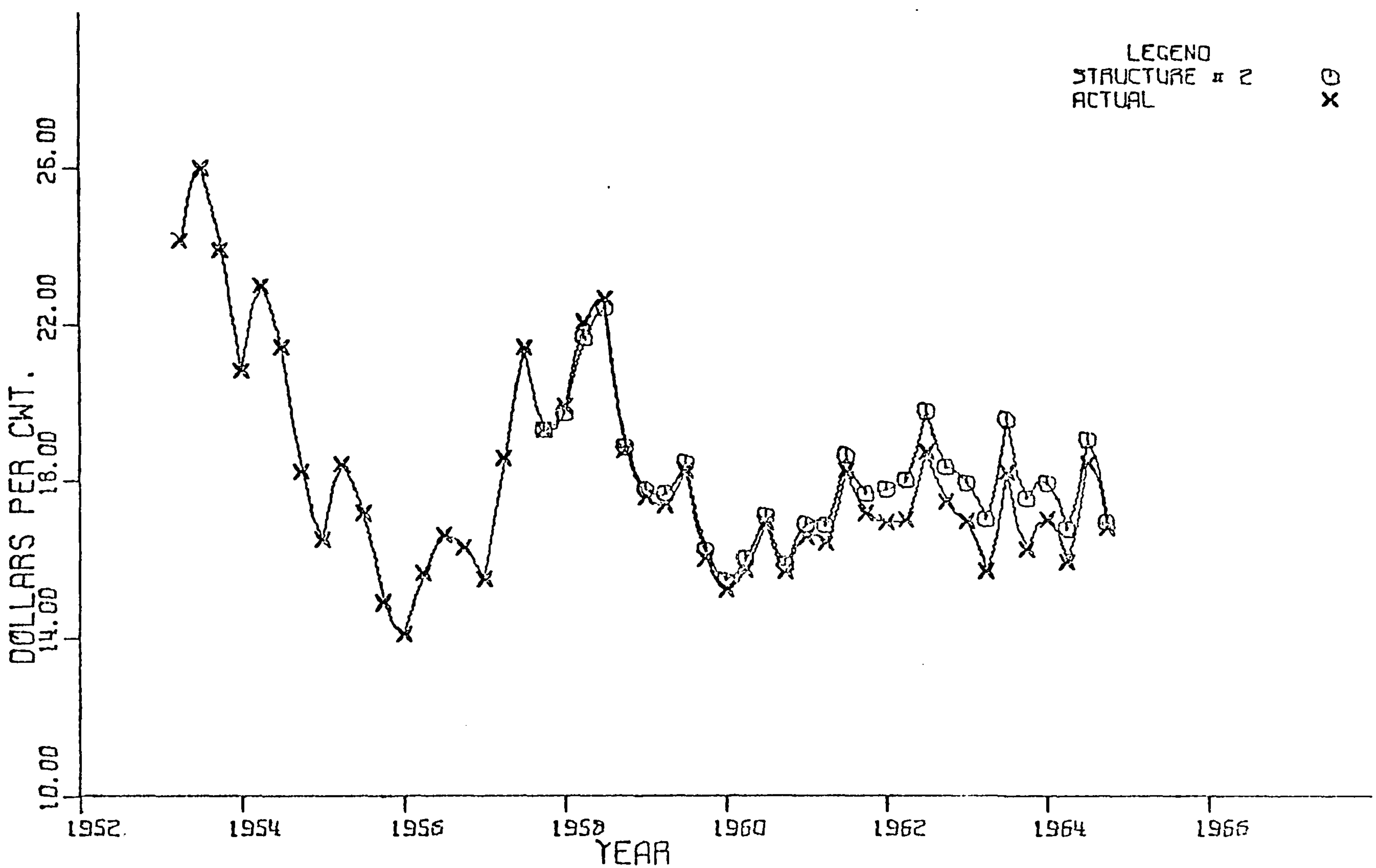

FIGURE 5.36 SIMULATED SLAUGHTER HOG PRICE USING CORN PRICE STRUCTURE NUMBER TWO AND SIMULATED USING ACTUAL CORN PRICE

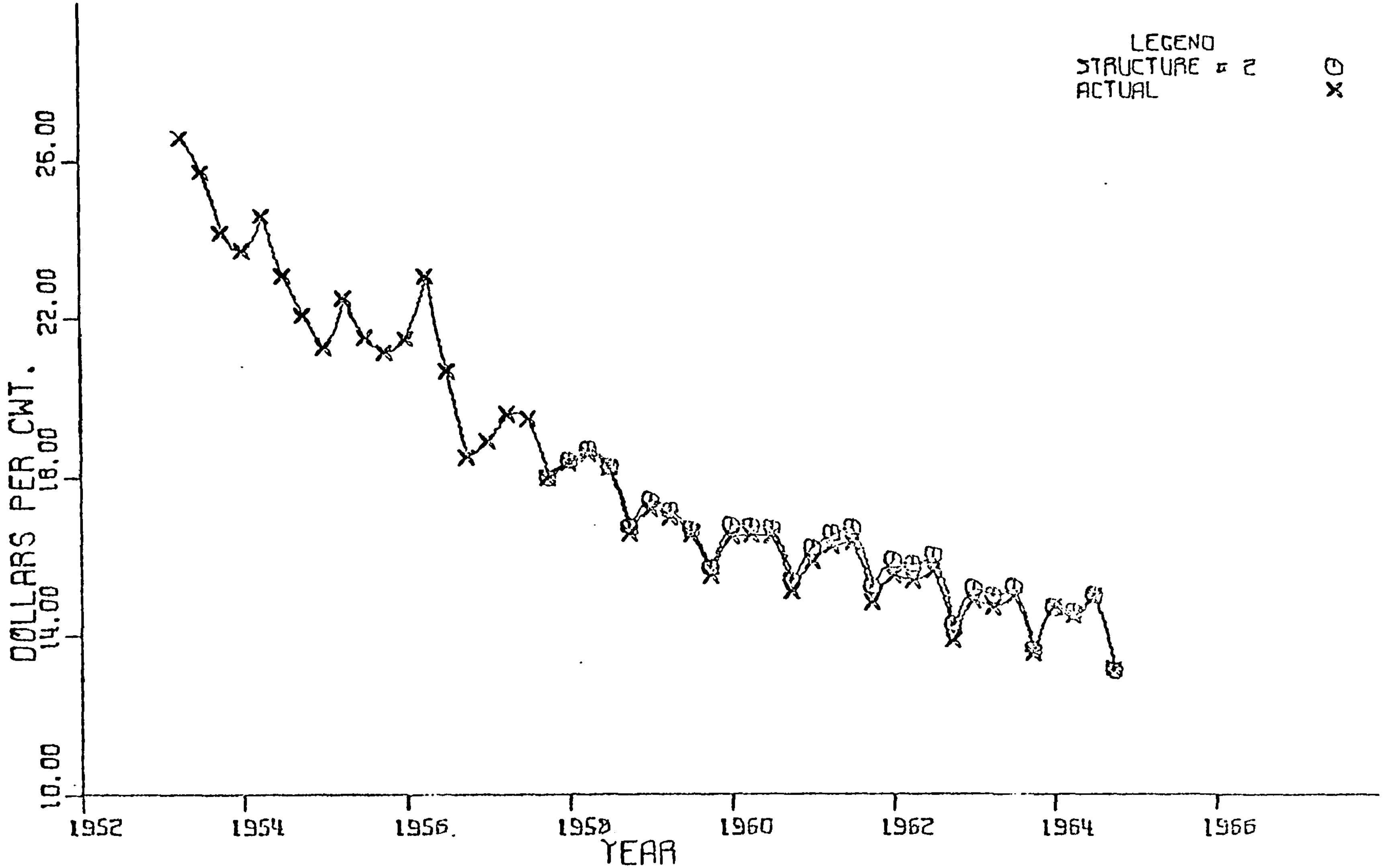

FIGURE 5.37 SIMULATED FARM BROILER PRICE USING CORN PRICE STRUCTURE NUMBER TWO AND SIMULATED USING ACTUAL CORN PRICE

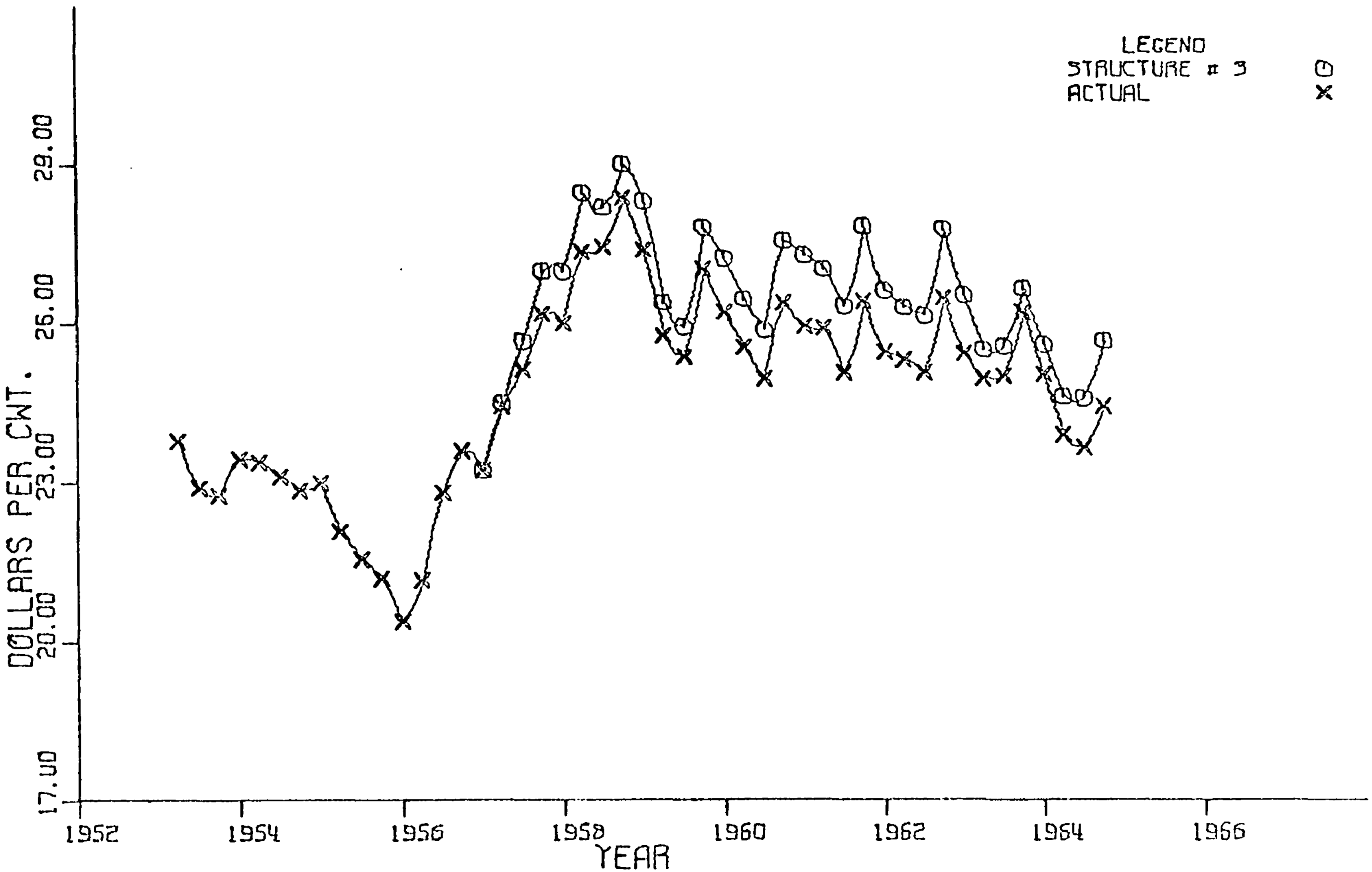

FIGURE 5.38 SIMULATED SLAUGHTER STEER PRICE USING CORN PRICE STRUCTURE NUMBER THREE AND SIMULATED USING ACTUAL CORN PRICE

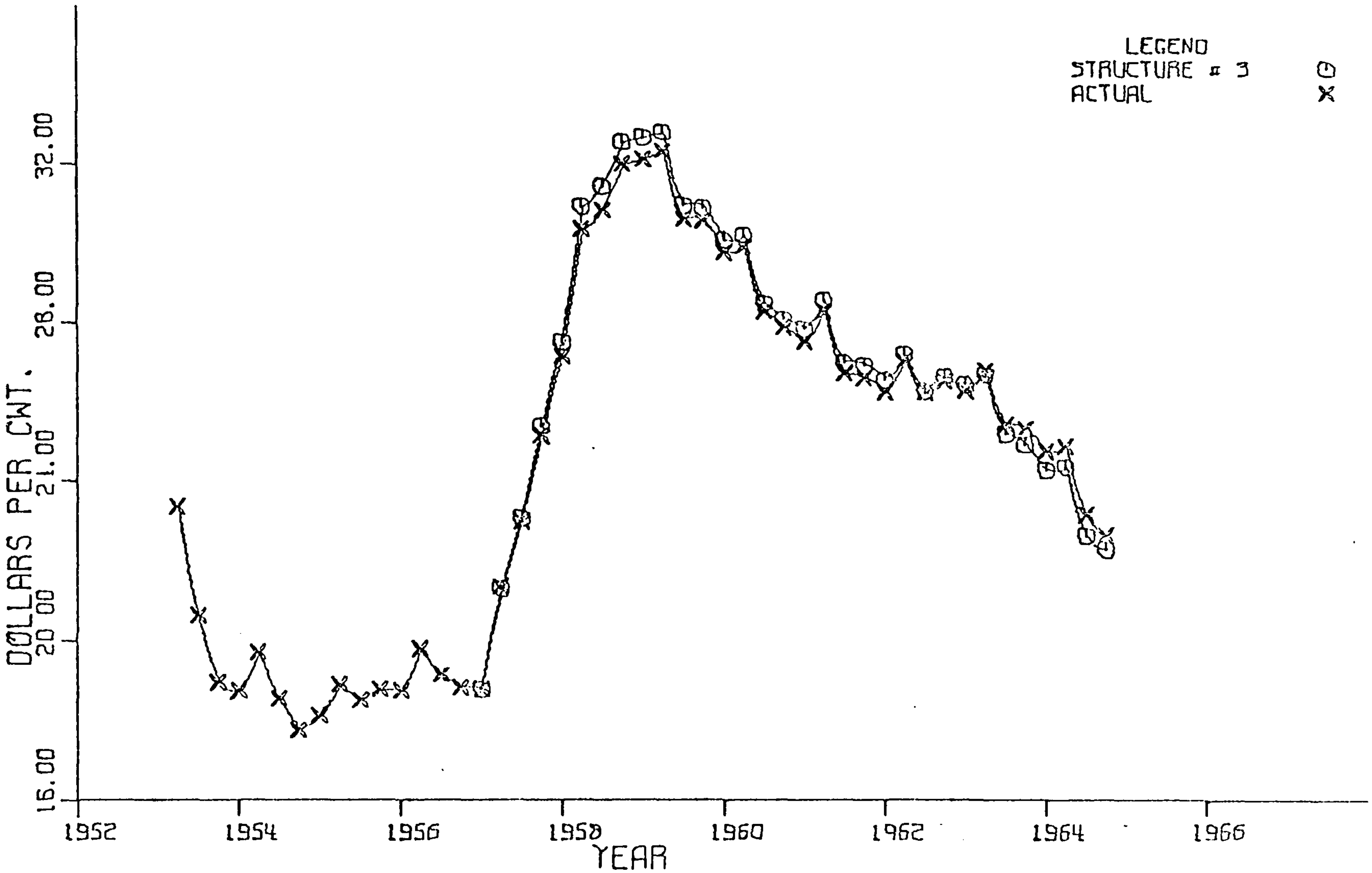

FIGURE 5.39 SIMULATED FEEDER CALF PRICE USING CORN PRICE STRUCTURE NUMBER THREE AND SIMULATED USING ACTUAL CORN PRICE

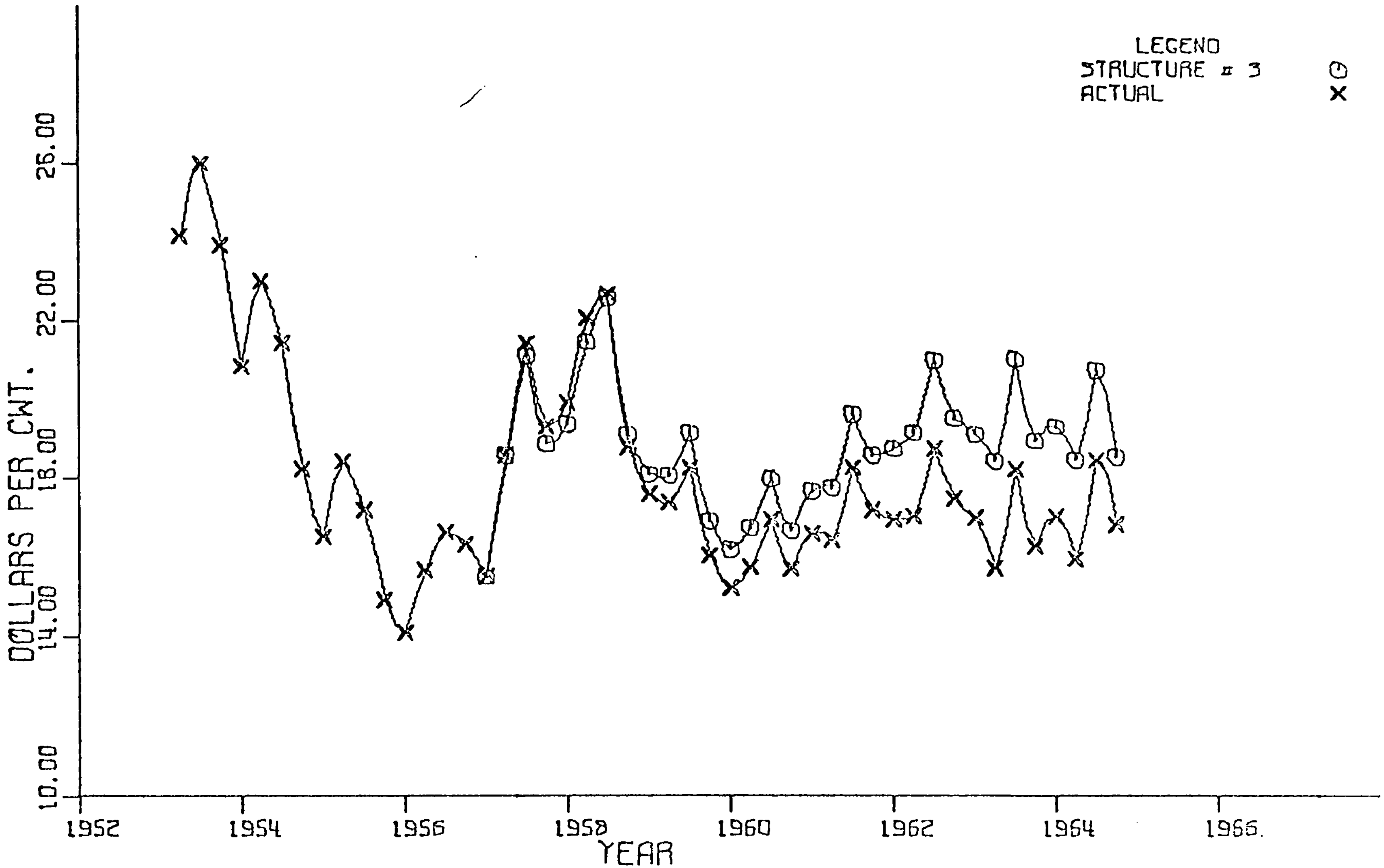

FIGURE 5.40 SIMULATED SLAUGHTER HOG PRICE USING CORN PRICE STRUCTURE NUMBER THREE AND SIMULATED USING ACTUAL CORN PRICE

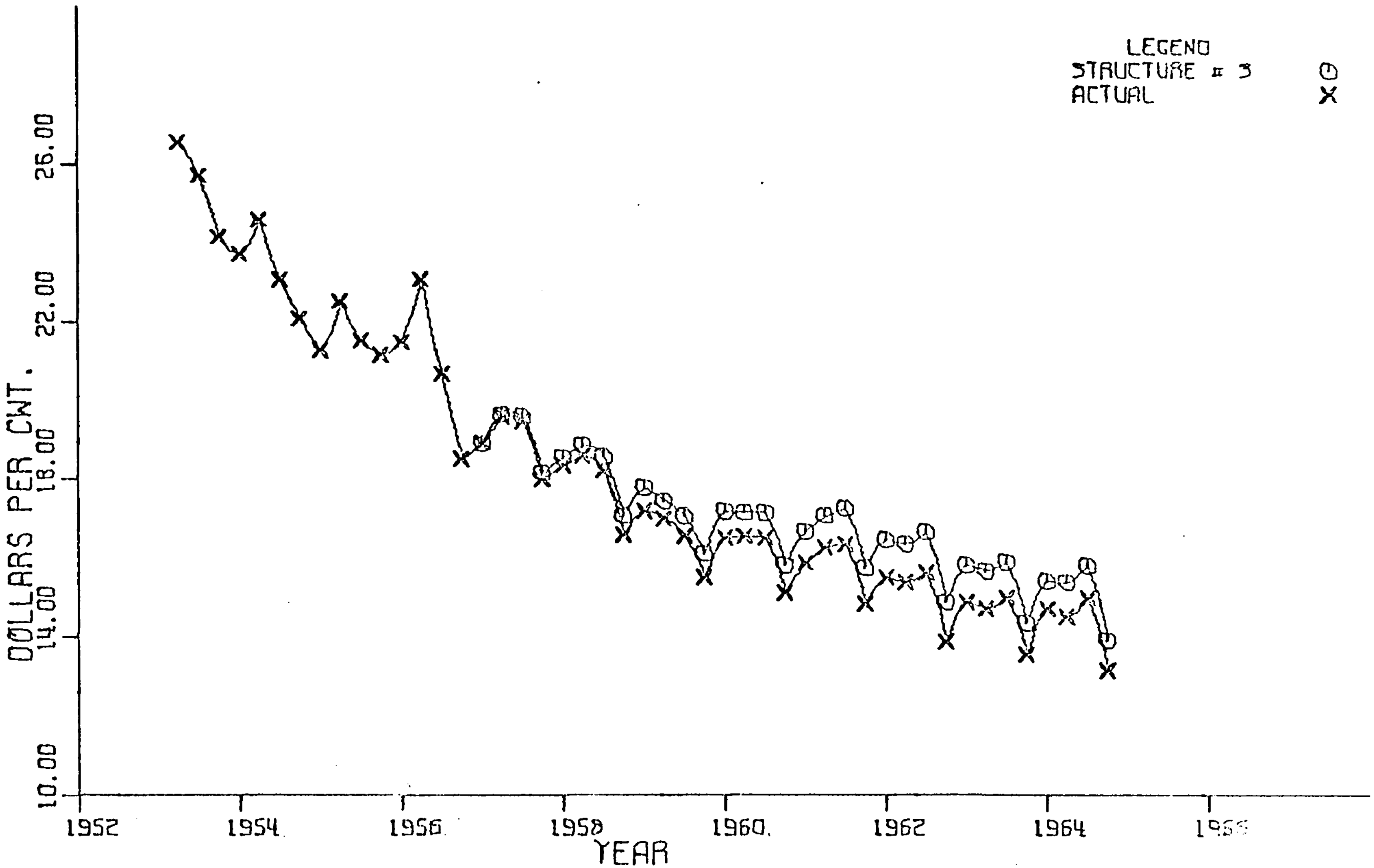

FIGURE 5.41 SIMULATED FARM BROILER PRICE USING CORN PRICE STRUCTURE NUMBER THREE AND SIMULATED USING ACTUAL CORN PRICE

To shed some light on the impact of the changed feed and product prices on livestock producers' net returns, three sets of partial budgets will be analyzed. Three common livestock enterprises were chosen; namely, feeder steer finishing, production of market hogs and commercial broiler production. In reality, however, beef, pork and poultry meat are the products of many diverse production processes. No attempt was made to specify the absolute level of profits. The investigation was restricted to estimating the change in profits for three typical production systems as a consequence of each of the three alternative structures for corn prices. In making "partial" budgets it is assumed that the only costs or returns altered are those which were re-estimated; namely, corn prices, feeder cattle prices and slaughter animal prices. All others are assumed constant. Initially partial budgets are estimated for net returns per animal. Later by comparing the change in per animal net returns and the national change in production, the aggregate change in returns for each of the three enterprises is estimated.

Change in per animal net returns is first estimated for the finishing of feeder cattle.[1] The feeding program is initiated in period t-3 with the purchase of a 450 pound feeder calf, and ends 348 days later in quarter t with the sale of a 1,075 pound mature steer. It is assumed that the animal is kept for a total of 84 days in the first quarter, 90 each in the second and third and 84 in the final quarter of the program. During the first quarter .911 bushels of corn are consumed. In the second through fourth quarters, respectively, 4.821, 17.464 and 30.875 bushels of corn are fed.

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[1]The input-output coefficients for the cattle and hog enterprises were obtained from the Iowa Farm Planning Manual (48, pp. 33, 42 and 47). The coefficients reflect typical Midwestern production organizations.

For each of the three alternative sets of corn prices and resulting systems of simulated endogenous variables, the change in net return is calculated by quarter, beginning with the first quarter for which different corn prices were used in the simulation model. For example, to estimate the change in net returns for the fourth quarter of 1962 under "Price Structure #3," the difference between the price of feeder cattle generated by the assumed corn prices and that generated by the historical exogenous data for the first quarter of 1962 were used to estimate the difference in cost of the feeder calf. Similarly, for each quarter the differences between the two sets of corn prices were applied to the afore described quantities consumed to ascertain the change in grain costs. The difference between the two generated prices of slaughter steers for the fourth quarter of 1962 reflects the change in gross return. The sum of the change in grain and feeder calf costs together with the change in return from the sale of the mature animal is the change in net return for this particular quarter.[1] The per animal change in net return for each

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[1]The change in net returns for the steer finishing operation was calculated by the following equation:

$$\begin{aligned}(\text{Change in net return steer finishing})_{j,t} &= 10.75 \\ &(SP_{j,t} - SP_{h,t}) - 4.5(SFP_{j,t-3} - SFP_{h,t-3}) \\ &- .911(CP_{j,t-3} - CP_{h,t-3}) - 4.821(CP_{j,t-2} - CP_{h,t-2}) \\ &- 17.464(CP_{j,t-1} - CP_{h,t-1}) - 30.875(CP_{j,t} - CP_{h,t}) \\ &t = 2,3,\ldots,48; \quad j = 1,2,3 \end{aligned} \tag{5.5}$$

where the subscript j designates the particular alternative "price structure" being analyzed, and h is associated with actual historical corn prices and livestock prices as generated by the simulation model from actual exogenous conditions.

alternative corn price structure is given by quarter in Table 5.8 and Figure 5.42.

The second enterprise analyzed is the production of market hogs. Hogs marketed in period t are assumed to be the offspring of sows farrowing in period t-3. One-seventh of the sow's feed bill is allocated to the market hog. During the last 45 days of quarter t-4, the pre-breeding and flushing period, the sow consumes 1.400 bushels of corn or .200 bushels per hog reared. In quarter t-3, 1.018 bushels of corn are allocatable to each hog marketed in period t. The cost of .818 bushels consumed by the sow in the first 45 days of quarter t-2 is charged to each hog of the litter recently farrowed.

The direct consumption of corn by the market hog is assumed to be .983 bushels in quarter t-2, 5.216 bushels in quarter t-1 and 4.232 bushels in the final quarter. The hog is kept for a total of 165 days during which it consumes 10.431 bushels or 584.2 pounds of corn to reach a market weight of 210 pounds. In addition, 2.036 bushels or 114 pounds of the sow's feed is allocated to each market hog.

Table 5.8 Steer finishing -- change in net return per animal between a simulated livestock-meat economy based on 1) alternative corn prices and 2) based on actual corn prices, first quarter 1957 to fourth quarter 1964

Year and quarter		Price structure Number one	Number two	Number three
		---------------- $ per head ----------------		
1957	1	0	0	0.14
	2	0	0	- 2.39
	3	0	0	- 0.06
	4	0	-1.28	0.60
1958	1	0	-1.03	- 0.33
	2	0	1.97	0.37
	3	0	0.89	- 3.22
	4	0	-2.15	- 6.64
1959	1	0	-1.73	- 5.77
	2	0	-3.32	- 9.76
	3	0	-3.77	-11.47
	4	0	-4.11	-11.84
1960	1	0	-2.91	-10.14
	2	0	-3.73	-12.04
	3	0	-4.48	-13.33
	4	0	-4.53	-13.08
1961	1	0	-3.35	-11.52
	2	0	-6.32	-15.65
	3	0	-6.26	-16.03
	4	-0.06	-4.59	-14.35
1962	1	0.20	-6.72	-16.18
	2	-0.26	-8.19	-19.51
	3	-0.79	-9.89	-21.72
	4	2.22	-6.51	-18.37
1963	1	2.11	-5.36	-16.97
	2	-0.19	-8.12	-21.93
	3	0.98	-6.84	-21.00
	4	-0.23	-7.84	-21.92
1964	1	0.91	-6.38	-20.17
	2	4.74	-3.91	-19.80
	3	5.79	-3.13	-19.23
	4	9.80	0.75	-15.22

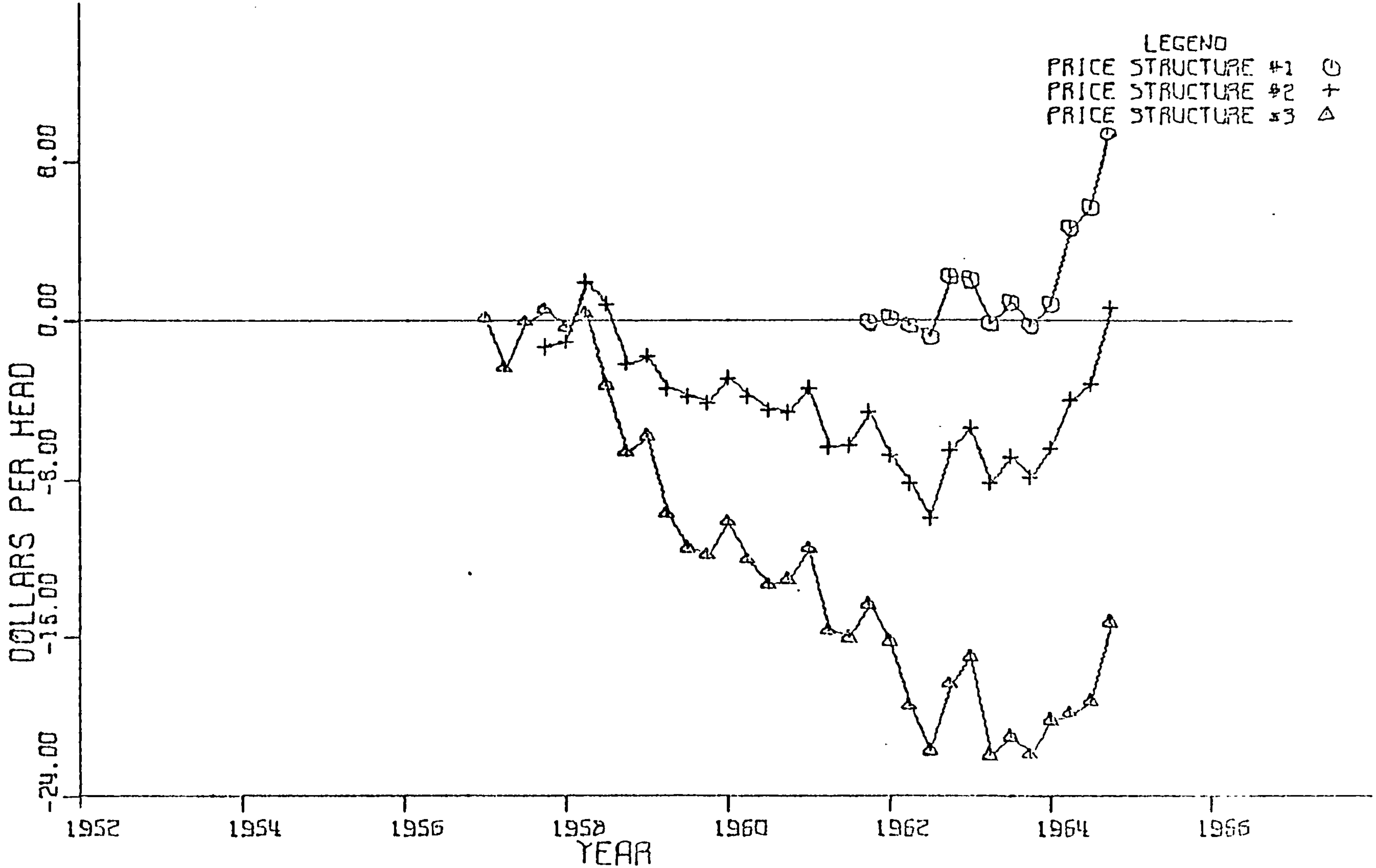

FIGURE 5.42 STEER FINISHING - CHANGE IN NET RETURN PER ANIMAL, SIMULATED LIVESTOCK-MEAT ECONOMY BASED ON HISTORICAL EXOGENOUS DATA COMPARED TO SIMULATED ECONOMIES BASED ON ALTERNATIVE HISTORICAL CORN PRICES

The change in net return per market hog was calculated in the same manner as outlined for the steer finishing program.[1] Hence, three different sets of quarterly estimates of change in net return per hog were derived, one corresponding to each of the three different livestock-meat economies simulated. These estimates are listed in Table 5.9 and graphically displayed in Figure 5.43.

The final enterprise analyzed for change in per animal net return is commercial broiler production. Based on experimental data (98), the total feed consumed by a 3.75 pound broiler is assumed to decline by .0727 pounds per quarter from 11.29 pounds in the second quarter of 1952 to 7.66 pounds in the fourth quarter of 1964. The price of broiler grower ration is assumed to adequately reflect the price of all broiler feed. Hence, the change in cost per bird was calculated by multiplying the quantity of feed

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[1]The change in net returns for the market hog operation was calculated by the following equation:

$$
\begin{aligned}
&(\text{Change in net return market hog})_{j,t} = 2.10 \\
&\quad (HP_{j,t} - HP_{h,t}) - .200(CP_{j,t-4} - CP_{h,t-4}) \\
&\quad - 1.018(CP_{j,t-3} - CP_{h,t-3}) - 1.801(CP_{j,t-2} \\
&\quad - CP_{h,t-2}) - 5.216(CP_{j,t-1} - CP_{h,t-1}) \\
&\quad - 4.232(CP_{j,t} - CP_{h,t}) \\
&\quad t = 2,3,\ldots,48; \qquad j = 1,2,3 \qquad (5.6)
\end{aligned}
$$

where the subscript j designates the particular alternative "price structure" being analyzed, and h is associated with actual historical corn prices and hog prices as generated by the simulation model from actual exogenous data.

Table 5.9 Hog production -- change in net return per animal between a simulated livestock-meat economy based on 1) alternative corn prices and 2) based on actual corn prices, first quarter 1957 to fourth quarter 1964

Year and quarter		Price structure Number one	Number two	Number three
		---------------- $ per head ----------------		
1957	1	0	0	0.03
	2	0	0	-0.34
	3	0	0	-1.70
	4	0	-0.27	-2.55
1958	1	0	-1.20	-3.34
	2	0	-1.85	-3.83
	3	0	-1.24	-2.58
	4	0	-0.51	-1.86
1959	1	0	-0.52	-1.84
	2	0	-0.27	-1.59
	3	0	-0.45	-1.42
	4	0	-0.84	-1.95
1960	1	0	-1.00	-2.20
	2	0	-1.02	-2.34
	3	0	-1.44	-2.70
	4	0	-1.77	-3.33
1961	1	0	-1.62	-3.37
	2	0	-1.43	-3.12
	3	0	-1.84	-3.53
	4	-0.01	-1.55	-3.50
1962	1	0.01	-0.44	-2.57
	2	0.01	-0.26	-2.13
	3	-0.26	-0.44	-2.34
	4	-0.27	-0.78	-2.93
1963	1	1.11	0.09	-2.26
	2	2.41	1.29	-0.69
	3	3.05	1.69	-0.39
	4	3.72	1.94	-0.42
1964	1	3.54	1.31	-1.30
	2	3.03	1.00	-1.11
	3	2.29	0.17	-2.11
	4	1.53	-0.77	-3.35

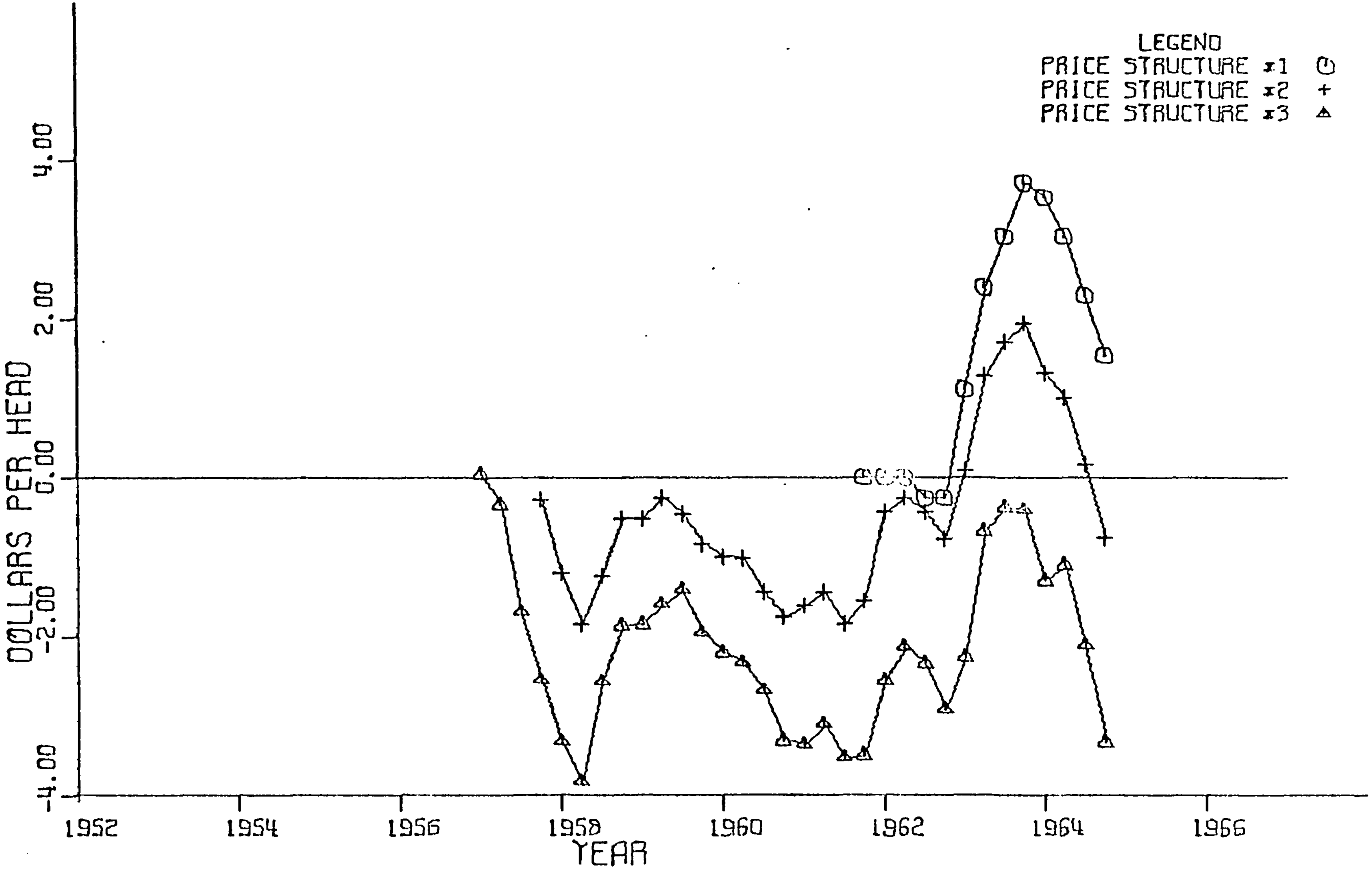

FIGURE 5.43 HOG PRODUCTION - CHANGE IN NET RETURN PER ANIMAL, SIMULATED LIVESTOCK-MEAT ECONOMY BASED ON HISTORICAL EXOGENOUS DATA COMPARED TO SIMULATED ECONOMIES BASED ON ALTERNATIVE HISTORICAL CORN PRICES

consumed in each quarter by the difference between the price of broiler grower simulated under the historical exogenous conditions and that simulated under one of the alternative sets of corn prices. Hence, the change in corn price indirectly influences the profitability of broiler production through its effect on the price of the manufactured feed.[1] The per bird changes in net return for the three alternative livestock-meat economies are given in Table 5.10 and Figure 5.44.

In general the net income per animal from producing each class of livestock decreased when the alternative corn price was greater than its historical level and improved when it was lower. One exception can be noted for hog production under "Price Structure #2." Beginning in the first quarter of 1963, the net return per animal from hog production increased over its historical level (Table 5.9 and Figure 5.43) even though the alternative price of corn was greater than historically observed (Table 5.4 and Figure 5.26). This resulted because the difference between the historical and hypothetical prices of corn

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[1]The change in net returns per broiler was calculated by the following equation:

$$(\text{Change in net return, broiler})_{j,t} = 3.75$$

$$(BRF_{j,t} - BRF_{h,t}) - (11.29 - .0727T_t)$$

$$(BRGP_{j,t} - BRGP_{h,t})$$

$$t = 2,3,\ldots,48; \quad j = 1,2,3 \qquad (5.7)$$

where the subscript j designates the particular alternative "price structure" being analyzed, and h is associated with actual historical corn prices and farm prices of broilers as generated by the simulation model from actual exogenous data.

Table 5.10 Broiler production -- change in net return per bird between a simulated livestock-meat economy based on 1) alternative corn prices and 2) based on actual corn prices, first quarter 1957 to fourth quarter 1964

Year and quarter		Price structure Number one	Number two	Number three
		---------------- ¢ per bird	----------------	----------------
1957	1	0	0	0
	2	0	0	-0.82
	3	0	0	-1.16
	4	0	-0.64	-1.57
1958	1	0	-1.08	-2.09
	2	0	-0.71	-1.83
	3	0	-0.37	-1.27
	4	0	-0.37	-1.45
1959	1	0	-0.18	-1.15
	2	0	-0.33	-1.64
	3	0	-0.63	-1.86
	4	0	-1.01	-2.46
1960	1	0	-0.86	-2.42
	2	0	-1.04	-2.84
	3	0	-1.49	-3.32
	4	0	-1.49	-3.58
1961	1	0	-1.19	-3.24
	2	0	-1.64	-3.88
	3	0	-1.75	-4.07
	4	0	-0.97	-3.50
1962	1	0	-0.97	-3.43
	2	-0.11	-1.27	-3.88
	3	-0.41	-1.64	-4.36
	4	0.52	-1.04	-3.99
1963	1	1.35	-0.48	-3.43
	2	1.42	-0.56	-3.47
	3	1.91	-0.11	-3.21
	4	2.02	-0.26	-3.66
1964	1	1.75	-0.71	-4.18
	2	1.79	-0.63	-3.92
	3	1.12	-1.31	-4.85
	4	1.45	-0.93	-4.67

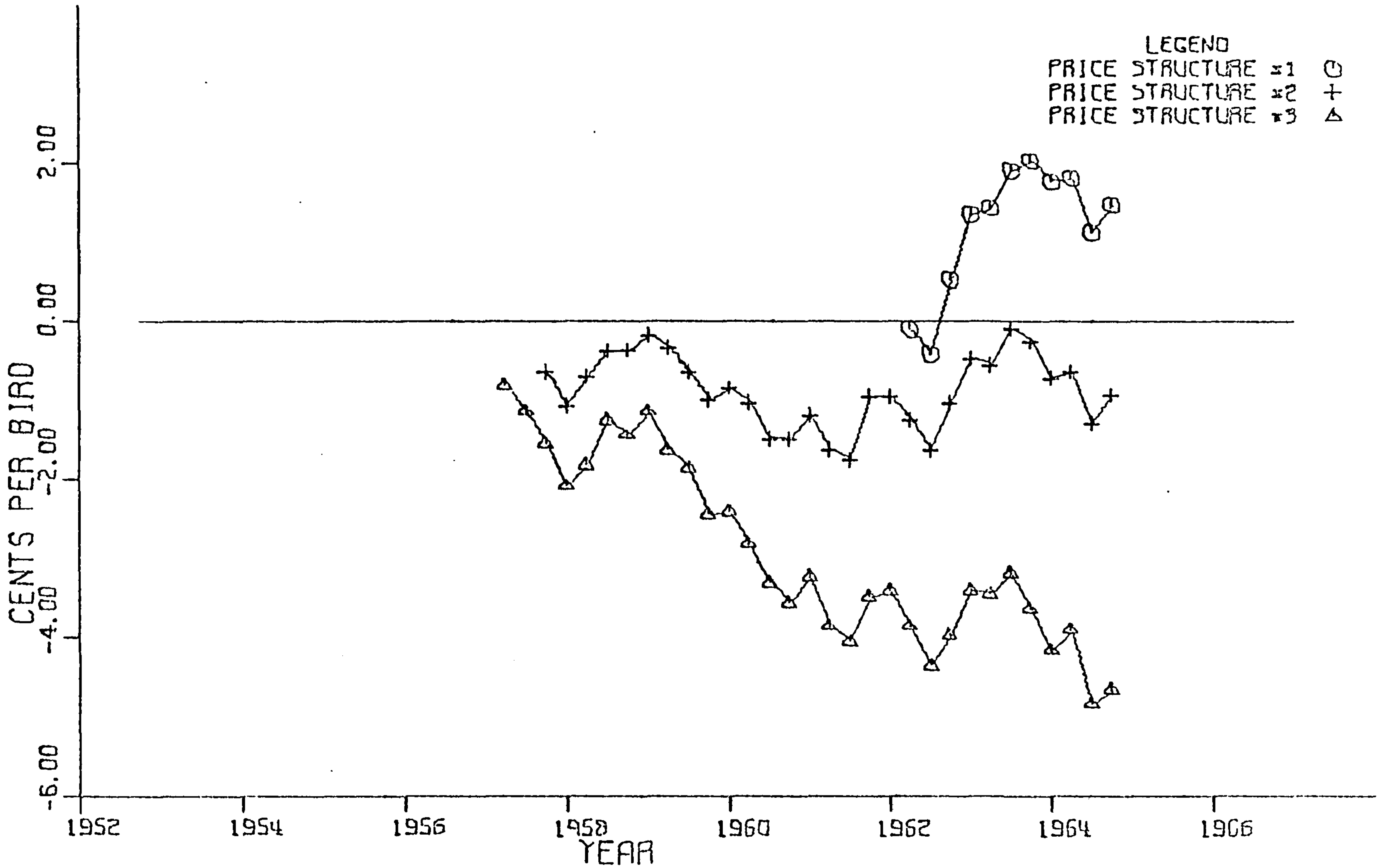

FIGURE 5.44 BROILER PRODUCTION - CHANGE IN NET RETURN PER BIRD, SIMULATED LIVESTOCK-MEAT ECONOMY BASED ON HISTORICAL EXOGENOUS DATA COMPARED TO SIMULATED ECONOMIES BASED ON ALTERNATIVE HISTORICAL CORN PRICES

decreased very rapidly during late 1962. The difference between the simulated price of hogs for "Price Structure #2" and the historically simulated price did not immediately decline as the difference between the two sets of corn prices disappeared, since a lapsed time of nearly a year was necessary before the output of the newly implemented production decisions was marketed. Hence, producers with hogs under "Policy Structure #2" in 1963 and early 1964 received a greater income per animal because while their feed costs were not materially greater, they were reaping the benefits of high hog prices due to previously depressed production resulting from relatively higher alternative corn prices.

While the general level of net income per animal of cattle feeders changed in the opposite direction to changes in feed grain (corn) prices, the per animal net income of ranchers would be expected to change in the same direction. Since very little grain is used in the latter type of production, no significant change in costs should occur as a result of the alternative price of corn. The simulated price of feeder calves does not, however, always change in the same direction as the price of corn. Under both "Price Structures #2 and #3" (Figures 5.35 and 5.39), the price of feeders increases somewhat over the historically simulated level during the initial period of increased corn prices. However, in both cases during the last 2 years of simulation, the price in the alternative economy fell below its historically estimated level. Given the relatively small difference between the simulated prices in both periods, it is unlikely that the net income of ranchers would significantly change in response to the level of corn prices.

The aggregate profit change must be examined for each enterprise. Each change in per animal net return may not change aggregate net return in the same direction. If output changes in the opposite direction from the change in per animal net return, the change in aggregate or enterprice profit may be opposite in sign from the change in per animal net return.

In Table 5.11 the quarterly marketings of steers, barrows and gilts and broilers in each of the alternative livestock-meat economies are expressed as a percentage of the associated output simulated from actual exogenous conditions. For example, steer slaughter is 7.53 percent greater in the first quarter of 1964 when the exogenous conditions relevant to "Price Structure #3" are assumed than simulated from actual exogenous data.

In many quarters both the per animal change in net return and the associated marketings changed in the same direction. In this case the aggregate return to resources of course also changed in the same direction. Hence, for example, hog producers in aggregate would have experienced a decline in net returns during the period 1958-2 to 1964-4 if corn prices had been much higher than were actually experienced ("Price Structure #3," Tables 5.9 and 5.11) since both the per animal change in net return and the number of animals marketed declined.

In those cases where the change in per animal net return and change in aggregate marketings are opposite in sign, the direction in which aggregate profit moves is less clear. For example, from 1958-3

Table 5.11 Percentage change in simulated marketings of slaughter steers, barrows and gilts and broilers for each of three alternative corn price structures compared to simulated marketings assuming actual corn prices

Year and quarter		STQ Alternative price structure			HQ Alternative price structure			BRQ Alternative price structure		
		#1	#2	#3	#1	#2	#3	#1	#2	#3
		percent								
1957	1	0	0	.00	0	0	.00	0	0	.00
	2	0	0	.03	0	0	.00	0	0	.00
	3	0	0	.03	0	0	-.02	0	0	-.22
	4	0	.00	-.19	0	.00	.18	0	.00	-.34
1958	1	0	.00	-.55	0	.00	.32	0	-.18	-.63
	2	0	-.33	-1.00	0	.12	-.19	0	-.30	-.74
	3	0	-.54	.48	0	.33	-2.06	0	-.25	-.76
	4	0	-.30	1.32	0	-.20	-2.60	0	-.44	-.67
1959	1	0	.74	1.64	0	-1.30	-3.53	0	-.24	-.32
	2	0	1.56	2.77	0	-1.79	-4.50	0	.14	.34
	3	0	.67	2.23	0	-1.45	-6.19	0	.06	.18
	4	0	.12	2.10	0	-1.05	-4.81	0	.07	.51
1960	1	0	.93	3.05	0	-1.96	-5.58	0	.08	.62
	2	0	.59	2.55	0	-2.11	-6.21	0	.27	.93
	3	0	.50	2.68	0	-1.98	-8.06	0	.12	.71
	4	0	.91	3.54	0	-1.82	-6.21	0	.00	.68
1961	1	0	1.40	4.14	0	-2.62	-6.91	0	.00	.80
	2	0	1.04	3.61	0	-2.87	-8.03	0	.19	.94
	3	0	1.15	3.91	0	-3.80	-11.26	0	.06	.72
	4	.00	1.73	4.98	.00	-3.47	-8.74	.00	.19	.94
1962	1	.00	2.37	5.72	.00	-3.96	-9.13	.00	.40	1.19
	2	.03	1.89	5.04	.00	-4.36	-10.68	.00	.64	1.39
	3	-.03	2.59	5.95	.01	-6.43	-15.45	-.05	.62	1.35
	4	-.17	2.99	6.87	.00	-4.73	-11.04	-.06	.82	1.69
1963	1	.11	1.84	5.78	.07	-3.99	-10.14	.06	.99	1.98
	2	.65	2.38	6.08	.08	-4.48	-12.02	.22	.98	1.85
	3	.89	2.79	6.70	-.72	-6.87	-17.27	.39	1.09	1.97
	4	1.77	4.07	8.56	-.46	-4.63	-11.93	.72	1.44	2.44
1964	1	.72	3.01	7.53	.85	-2.84	-9.85	.76	1.41	2.46
	2	-.61	1.41	5.58	2.00	-2.75	-11.54	.56	.97	1.90
	3	-.63	1.56	5.82	3.09	-3.84	-16.03	.61	.98	2.00
	4	-1.62	.88	5.70	3.75	-1.30	-9.89	.36	.77	1.89

through 1964-4 steer slaughter increased for the alternative livestock-meat economy associated with the much higher than historically observed corn prices. During this period the per steer net return was estimated to be lower than historically experienced. However, it seems likely that the net return declined more than the slaughter increased. If the per animal total net return in this period was in the neighborhood of $20 to $30 under the historical conditions, then the per animal net return for this alternative economy would decline at least 15 percent and perhaps even 100 percent. Marketings increased approximately 1 to 8 percent (Table 5.11). Hence, it is evident that total profit in this enterprise as well as per animal profit would have declined if higher corn prices had existed.

The aggregate returns to the hog industry under each of the assumed alternative economies would in general have changed in the same direction as the per animal change in net returns. In most quarters the change in profits per hog and the percentage change in their marketings have the same sign (Tables 5.9 and 5.11). The period 1963-1 through 1964-3 for the simulated economy associated with "Price Structure #2" is an exception to this observation. If total profit per hog under the original conditions was in the range of $5.00 to $10.00 per head, then the increase in return per animal in the period 1963-2 to 1964-3 would be from 5 to 10 percent. The percentage decline in marketings would thus not be sufficient to offset the greater return per animal, with a larger aggregate profit thus accruing in this period.

In most quarters the marketings of broilers increased under the alternative exogenous conditions compared to the historically simulated economy (Table 5.11). However, in many of these quarters per bird profits declined (Table 5.10). In examining the most extreme alternative set of corn prices ("Price Structure #3"), the 2 to 4 cent per bird decline in profits would correspond to a decline of from 5 to 20 percent. Hence, the 1 to 2 percent increase in marketings would be insufficient to offset the greater percentage decline in per bird profits, resulting in lower aggregate returns to broiler producers under this alternative economy.

Individual producers who contracted or expanded their enterprises by the same percentage as the national totals would experience the same changes in their aggregate profits as was outlined for the industries in total. In a nation where very diverse types of production organizations exist for any one type of enterprise, one would not expect all producers to change their output in the same manner.

One further source of individual farm differences in profits resulting from the alternative structures of corn prices results from the diversity in feeding efficiencies among farmers. For example, a producer who achieved a 20 percent greater feeding efficiency for hogs than was assumed in this study would require a total of 9.974 bushels of corn per hog. Under this assumption the change in net return per hog for 1964-4 under "Price Structure #3" is -$1.94 compared to -$3.35 based on the original assumptions. In this particular example even an extremely different assumption about feed consumption was not sufficient to yield an increase in per animal net return over the historically simulated economy. However, if one was to compare producers who were extremely efficient with ones who were extremely inefficient, situations undoubtedly exist where the change in net return per animal would be positive for the more efficient while negative for the other.

CHAPTER VI. SUMMARY AND CONCLUSIONS

During the past several decades the Federal Government has intervened substantially in the markets for feed grains. Feed grain prices as a result have been maintained at a level greater than would otherwise have prevailed and the income position of grain farmers has as a consequence been improved. A question has persisted, however, as to whether or not the artificially high prices for feed grains have been to the detriment of the incomes of livestock producers. The hypothesis of this study was that the higher feed grain prices would cause a sufficient reduction in livestock output that not only would livestock prices increase, but that they would be sufficiently greater to offset the higher feed costs, resulting in a net income gain to livestock enterprises.

To determine the influence of feed grain prices on livestock prices, it was necessary to construct an econometric model of the livestock-meat economy. This model consisted of 35 demand, supply, inventory and technological equations relating the various segments of the livestock-meat industry. The structure was recursive with one simultaneous subset.

A critical assumption in the specification of this model was that grain price, but not the level of feed grain production, influenced the prices and outputs of livestock. It was assumed that sufficient surplus stocks of feed grains were available so that their price was the only consideration in determining whether to increase or decrease livestock production.

The parameters of the econometric model were estimated by regression analysis applied to quarterly and annual time-series data from the period 1953 to 1964. With the exception of the January 1 heifer inventory relationship, all equations were estimated by schemes which accounted for autocorrelation in the errors.

Since the econometric model was complete in the sense that an equation was specified for each endogenous variable, it was possible to use the system of equations as a simulation model. Given a set of initial conditions, the endogenous variables could be estimated for as many periods as one wished to make estimates of the exogenous variables.

The simulation model was initially verified through its ability to reproduce the time paths of its endogenous variables over the period of coefficient estimation, given first quarter 1953 data as initial conditions and the values of all exogenous data for the period. Some adjustments in equations were made to improve its simulation ability, but generally it reproduced the historical paths satisfactorily.

Since data for 1965 and the first two quarters of 1966 were available, but had not been used in the specification or estimation of the model, a final check of the model's simulating ability was carried out by predicting this recent period given 1964 initial conditions and the 1965 and 1966 actual population income and other exogenous variables. The model in general performed less well in 1965-1966 than in the earlier period.

Once the model was felt to adequately reproduce the time paths of the endogenous variables, three different hypothetical sets of corn prices were used as exogenous data. Corn prices lower, much higher and more stable than actual were used. Three alternative livestock-meat economies to the actual historical were simulated for the period up to the end of 1964. By comparing simulated results under historical and alternative grain price paths, the effect of grain price on the livestock-meat economy was observed.

The simulation model was used to predict the values of the endogenous variables (i.e., simulate the livestock-meat economy) for all periods to the end of 1969 on the basis of second quarter 1966 initial conditions and reasoned estimates of the future values of the exogenous variables.

The change in net return per animal as a result of the alternative structure of historical corn prices was calculated for market hog, broiler and steer finishing enterprises for each quarter in which the different corn prices were used. It was found that while the prices of slaughter livestock moved in the same general direction as corn prices, the increase in output price was not sufficient to offset the increased feed costs. Ranchers would experience little change in net return per animal. While their costs of production would not materially rise with feed grain (corn) prices, the price of feeder calves also did not significantly change in response to the level of these prices.

Many livestock producers are also grain farmers; thus, a mere exchange of currency could take place between the livestock and field crop enterprises. The producer may feel that his livestock enterprise is less profitable when corn prices increase. Or he may feel livestock production is more profitable when higher livestock prices are observed. However, the results of this study indicate that while higher livestock prices are associated with favorable levels of corn or grain prices, if the grain consumption of livestock is costed at its market value, the net returns of the livestock enterprise will not increase with these livestock prices, and may be lower. Thus, the returns to resources in livestock production are not improved, according to the results of this study, by raising feed grain prices.

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ACKNOWLEDGEMENTS

The author is indebted to Professor Arnold A. Paulsen for his inspiration, insights and critical comments throughout the course of his graduate program.

Appreciation is extended to Drs. George W. Ladd, Lehman B. Fletcher, Wayne A. Fuller and Lee R. Kolmer for their helpfulness and for serving on the author's graduate committee.

Special thanks are due to Miss Bonnie Ryerson for her skillful typing of both the preliminary and final drafts of the dissertation.

To my wife Doreen and family, I am forever grateful for their forbearance and encouragement throughout my graduate career.

APPENDIX

Table A.1 Exogenous data used in econometric model of livestock-meat economy for first quarter 1953 to second quarter 1966

Year and quarter		Variable code name									
		P	BMN	PMN	PTN	RYN	RCPI	RFMW	G	CP	CDS
1953	1	155,510	.707	.611	-.116	45.13	1.451	.022	70.3	1.595	23,549
	2	156,093	.999	.474	.103	56.30	1.045	.020	73.3	1.578	–[a]
	3	156,742	.823	.396	.102	45.47	1.470	.012	76.7	1.576	–[a]
	4	157,559	.654	.501	.063	22.64	1.465	.027	74.3	1.522	–[a]
1954	1	158,362	.960	.537	.076	6.81	.950	.032	72.3	1.556	23,896
	2	159,092	.698	.421	.157	-19.02	.374	.021	72.7	1.572	–[a]
	3	159,839	.619	.325	.113	-32.85	.269	.009	76.0	1.625	–[a]
	4	160,675	.653	.517	.100	-26.68	- .506	.004	71.3	1.553	–[a]
1955	1	161,469	.607	.347	.111	-27.52	-1.181	-.017	69.7	1.514	23,462
	2	162,261	.672	.425	.062	-12.35	-1.626	-.029	67.3	1.468	–[a]
	3	163,097	.619	.300	.116	1.82	-1.706	-.043	78.3	1.417	–[a]
	4	163,922	.610	.360	.061	6.99	-1.777	-.029	77.0	1.223	–[a]
1956	1	164,708	.559	.370	.006	7.16	-2.352	-.024	71.7	1.251	22,912
	2	165,447	.623	.338	.060	7.33	-2.457	-.018	70.7	1.432	–[a]
	3	166,211	.656	.325	.066	7.50	-1.463	-.026	72.0	1.542	–[a]
	4	167,065	.587	.359	-.042	21.67	-1.138	-.028	64.3	1.398	–[a]
1957	1	167,848	.548	.328	-.054	17.84	- .913	-.002	62.7	1.325	22,325
	2	168,546	.546	.320	.036	17.01	- .458	-.005	72.0	1.307	–[a]
	3	169,256	.496	.225	-.041	23.18	.336	-.013	85.0	1.322	–[a]
	4	170,119	.500	.306	.035	6.34	.421	-.004	82.3	1.203	–[a]

[a]The dairy cow inventory, CDS, is observed annually rather than quarterly.

Table A.1 (Continued)

Year and quarter		Variable code name									
		P	BMN	PMN	PTN	RYN	RCPI	RFMW	G	CP	CDS
1958	1	170,945	.515	.269	.053	-19.49	.746	.011	82.0	1.128	21,265
	2	171,628	.530	.286	.111	-30.32	1.471	.010	84.0	1.255	—[a]
	3	172,614	.550	.307	.110	-23.15	1.335	-.009	85.0	1.345	—[a]
	4	173,416	.479	.271	.115	-15.98	.960	-.004	82.3	1.177	—[a]
1959	1	173,942	.437	.241	.103	- 8.81	.545	.012	78.0	1.172	20,132
	2	174,676	.567	.303	.120	5.36	.310	.014	76.3	1.260	—[a]
	3	175,422	.490	.251	.068	- 3.47	.634	-.004	80.3	1.275	—[a]
	4	176,228	.460	.238	-.006	-24.30	.819	.001	79.3	1.120	—[a]
1960	1	176,936	.446	.249	.073	- 5.14	.514	.022	75.0	1.122	19,527
	2	177,588	.501	.282	.039	-11.97	.569	.024	76.0	1.189	—[a]
	3	178,308	.533	.275	.123	-19.80	.633	.009	81.3	1.193	—[a]
	4	179,128	.469	.234	.039	-39.63	.688	.005	77.7	1.061	—[a]
1961	1	179,884	.439	.239	.028	-62.46	.583	.012	76.0	1.082	19,361
	2	180,611	.504	.255	.055	-50.29	.208	.010	76.3	1.106	—[a]
	3	181,349	.466	.259	.072	-34.12	.192	-.004	79.3	1.126	—[a]
	4	182,024	.571	.335	.082	-25.95	.187	-.008	78.0	1.098	—[a]
1962	1	182,566	.460	.279	.121	-14.78	-.188	.005	74.7	1.078	19,167
	2	183,210	.502	.295	.136	- 6.62	-.033	.005	75.7	1.124	—[a]
	3	183,965	.533	.277	.092	-15.45	-.108	-.015	82.7	1.117	—[a]
	4	184,827	.498	.298	.108	-19.28	.116	-.016	80.0	1.095	—[a]

Table A.1 (Continued)

Year and quarter		Variable code name									
		P	BMN	PMN	PTN	RYN	RCPI	RFMW	G	CP	CDS
1963	1	185,516	.491	.286	.070	-13.11	-.319	.001	76.3	1.166	18,679
	2	186,118	.505	.296	.032	-17.94	-.466	.006	75.0	1.215	a
	3	186,557	.488	.311	.048	- 2.77	-.109	-.014	79.0	1.310	a
	4	187,320	.491	.283	-.011	10.40	-.185	-.011	76.7	1.227	a
1964	1	188,222	.521	.367	-.117	36.58	-.160	.012	73.3	1.200	18,088
	2	188,822	.688	.286	.000	69.74	-.395	.018	73.0	1.242	a
	3	189,491	.718	.338	.047	80.91	-.370	-.002	76.7	1.243	a
	4	190,212	.673	.321	.089	87.08	-.386	.001	75.3	1.214	a
1965	1	190,846	.561	.257	.136	98.80	-.421	.007	72.3	1.264	17,592
	2	191,392	.664	.340	.261	107.52	-.366	.014	74.3	1.333	a
	3	191,978	.734	.307	.276	147.24	-.052	-.010	84.3	1.317	a
	4	192,546	.836	.369	.254	194.96	-.017	-.007	81.7	1.203	a
1966	1	193,001	.746	.332	.388	208.68	.408	-.001	79.3	1.267	16,607
	2	193,386	.858	.310	.367	213.39	1.233	.034	77.7	1.270	a

Table A.2 Estimated exogenous data used in projection of livestock-meat economy from the third quarter 1966 to the fourth quarter 1969

Year and quarter		Variable code name									
		P	BMN	PMN	PTN	RYN	RCPI	RFMW	F	CP	CDS
1966	3	193,800	.724	.321	.227	220.00	1.200	.020	76.3	1.393	_a
	4	194,456	.724	.321	.227	210.00	1.150	.010	77.8	1.370	_a
1967	1	195,112	.724	.321	.227	205.00	1.000	0	75.0	1.460	16,067
	2	195,767	.724	.321	.227	200.00	1.000	0	76.0	1.510	_a
	3	196,423	.724	.321	.227	200.00	1.000	0	81.0	1.520	_a
	4	197,079	.724	.321	.227	200.00	1.000	0	77.8	1.310	_a
1968	1	197,735	.724	.321	.227	200.00	1.000	0	75.0	1.230	15,472
	2	198,391	.724	.321	.227	200.00	1.000	0	76.0	1.270	_a
	3	199,047	.724	.321	.227	200.00	1.000	0	81.0	1.300	_a
	4	199,703	.724	.321	.227	200.00	1.000	0	77.8	1.210	_a
1969	1	200,359	.724	.321	.227	200.00	1.000	0	75.0	1.180	14,877
	2	201,015	.724	.321	.227	200.00	1.000	0	76.0	1.230	_a
	3	201,671	.724	.321	.227	200.00	1.000	0	81.0	1.250	_a
	4	202,327	.724	.321	.227	200.00	1.000	0	77.8	1.150	_a

[a] The dairy cow inventory, CDS, is observed annually rather than quarterly.