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AN ECONOMETRIC MODEL OF U.S. LIVESTOCK AND POULTRY SECTOR FOR POLICY ANALYSIS AND LONG-RUN FORECASTING: TESTING OF PARAMETER STABILITY AND STRUCTURAL CHANGE

By

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ABSTRACT

AN ECONOMETRIC MODEL OF U.S. LIVESTOCK AND POULTRY SECTOR: FOR POLICY ANALYSIS AND LONG-RUN FORECASTING: TESTING OF PARAMETER STABILITY AND STRUCTURAL CHANGE

By

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The major problem in empirically tracking changes in demand structure due to changes in consumer preferences is that shifts in the utility function are not directly measurable. Given this problem, empirical attempts to identify structural change in meat demand by ad-hoc procedures and varying-parameter techniques have serious limitations. One criticism pertains to the inability of these procedures to distinguish between structural change and model misspecification.

This paper explores the systematic use of several statistical procedures to minimize the problems associated with ad-hoc analysis of structural change. Specifically, the study uses a three-stage approach in investigating changes in demand structure for beef, pork, broiler, and turkey meat. The approach is useful in detecting structural change as well as misspecification in the context of simple models.

Meat demand models were constructed in the context of developing an annual forecasting model for U.S. livestock and poultry sector. The recursive least squares parameter estimates for beef, pork, and broiler inverse demand models

varied over the 1955-1985 period. Two periods with very different patterns are identified: 1961-1976 and 1977-1985. The average size of the residuals is greater in the second period than in the first period. Second, a tendency to overpredict in the second period is evident. The forward one-step recursive residuals for beef, pork, and broilers deviate from what we expect from the null hypothesis of constant regression parameters.

Use of several statistical procedures suggest that structural change in market demand for beef, pork, and broilers occurred about 1976-1977. Health concerns may be the cause but no sound data exists to permit testing this possibility. The three-stage approach is useful in determining the timing of change and pattern of variation in demand parameters.

A major conclusion of the study is the inadequacy of a constant parameter formulation for the demand of the three meats. Results indicate an increase in the absolute value of own-quantity flexibility for beef and pork. The higher flexibility has implications for price stability and price levels as market structure changes. Government programs on feed grains which indirectly affect livestock quantity, will now have a greater impact on meat prices.

To my parents

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CHAPTER 1

INTRODUCTION

Structural changes in supply and demand relationships have been suspected in the U.S. livestock sector. In particular, structural changes in the U.S. demand for red meat has been suspected to have occurred sometime in the mid to late 1970's. The changes are hypothesized to be the result of the increasing concern of consumers about cholesterol and the change in beef grading starting in the mid-1970s. (Chavas, 1983). A change in the income distribution in the late 1970's is also alleged to have caused the change in the structure of demand for red meat (Unnevehr, 1986).

The answers to the question about why and how structural changes take place in the livestock sector and other agricultural subsectors have value in policy formulation and implementation. Knowledge about the structural change process could provide insights on how policies and programs affect the structure of agricultural sectors. This predictive knowledge may be added to the set of information used by policy makers and decision makers in determining what policies have to be formulated to foster a desired structure of agricultural sectors.

Current research (Reimund, Martin and Moore, 1981; Hayenga et.al., 1985; Hilker, et.al., 1986) have given some insights about structural change in the U.S. livestock sector. Analysts and model builders, however, are continously challenged to account for the structural changes in the specification of structural models for policy analysis and for forecasting the implications of such changes to the growth prospects of relevant sectors.

The Michigan State University Agriculture Model (MSUAM) has recently found it difficult to provide accurate projections of livestock production and prices. Several reasons were given for this difficulty, but foremost was the failure to account for the substantial structural changes that have occurred in the U.S. livestock production and demand for meat.

Other forecasting models have been found to exhibit the same deficiency. Braschler (1983) indicated that during the 1960's and through 1973, reasonably accurate projections of both pork and beef prices at the farm and retail levels are provided by econometric models with single equation demand systems. Projection errors were primarily attributed to the errors in projections of supply variables and consumer income. Starting in the early 1970's, however, errors in price projections were considerably larger than those of the 1960's even under reasonable estimates of supply and consumer income. Tomek and Robinson (1977) likewise observed that projections of beef prices during the early 1970's based on data prior to 1969 were largely underestimated.

There is, therefore, a need for forecasting and policy models to accommodate and track structural change. Consideration of structural change in modeling livestock supply and demand is not only crucial to the ability of models to provide accurate forecasts but is also necessary for the structural models to be of continous relevance and value in the important task of analyzing government programs and policies.

1.1 Focus of the Problem

Difficulties in developing a model that captures the relationships useful for forecasting and policy analysis in economics have been recognized. One aspect of the problem pertains to the question of how to capture the effects of the unobservable variables which have important effects on the behavior and magnitude of the structural parameters defining the economic relationship of interest. (Rausser, et.al., 1981).

In the context of supply and demand analysis, Rausser, et.al. (1981) identified the unobservable variables to include changes in tastes and preferences and evolution of habits, formation of expectations, changes in institutional arrangements, and technological change. These unobservable phenomena are hypothesized to result in structural changes in supply and demand relationships over time.

The hypothesis of a change in the structure of demand and supply for meat commodities in the United States is of particular relevance and interest. Whether or not there has been a structural change in the demand for meat products raises important policy questions and poses interesting questions about the choice of an appropriate econometric model for forecasting purposes.

If the decline in demand for red meat during the 1970's is strictly due to changes in market variables, then policies that improve meat production and marketing efficiencies will result in lower prices of red meat and will be expected to enhance the quantities of red meat demanded. However, if the observed decline in red meat demand is a result of non-market factors such as preference and habit changes, then a different policy action may be needed to get a desired result. To enhance demand and long-run industry output, policies to upgrade the quality of red meat products (e.g., producing leaner meat) might be required.

Furthermore, if the structural change resulted in more inelastic demand or more flexible price for a particular meat, then changes in the available supply of meat will increase the variation in farm prices of meat, ceteris paribus. This has implications regarding the effectiveness of policies designed to influence meat supply and prices after a structural change has occurred.

Another important implication of structural change involves the choice of an appropriate econometric model for forecasting. Common econometric procedures require the constancy of parameters.[1] This condition of constancy of parameters is usually assumed. If structural change in the demand relationship has occured for U.S. meat products, this assumption is obviously inappropriate and unjustified. Hence, a model specification that considers the likely shifts (e.g., abrupt and/or systematic) in the demand and supply structural parameters would have to be considered.

1.2 Research Objectives

The objectives of this study are as follows:

a. to detect and test whether structural change has occured in the U.S. demand for beef, pork, broiler, and turkey.

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[1] This implies a single parameter vector defining the relationship between endogenous and explanatory variables and constant set of error process.

b. to include the structural change in demand in the specification of the livestock demand component of the MSUAM;

c. to include some aspects of structural change in livestock production in the specification of the livestock supply component of the MSUAM;

d. to estimate the changes in the structural demand parameters over time and determine the implications of such parameter changes on livestock production and prices.

1.3 Hypothesis About Change in the Structure of U.S. Demand for Meat

Several hypotheses have been presented regarding possible causes of structural change in the U.S. demand for meat during the 1970's. The increasing consciousness of consumers about the ill effects of fat and cholesterol and the changes in consumer lifestyle may have resulted in preference shifts away from red meat.

The hypothesis of changing preferences in demand for meat has been suggested in some studies. Phlips (1974) considered the possibility of changes in preferences over time in demand analysis. Insights into how changes in preferences might affect demand and what caused such changes are discussed in Green (1978). Green identified three factors which might cause a change in the preferences of consumers. The three factors include the effects of advertising, the effects of choices made by other consumers, and the effects of longer term impact of price changes.[2]

Another hypothesis pertains to the increase in the opportunity cost of time of the consumer and its negative effect on at-home beef consumption (Chavas, 1986). The change in the structure of households is also alleged to cause the decline in red meat demand. Chavas indicated that the increase in single individual households may result in changes in the structure of demand for meat.

1.4 Review of Relevant Research

Efforts to capture and model useful relationships for projection purposes in agricultural economics and other nonexperimental disciplines have been faced with difficult challenges. Starting in the early 1970's, practitioners have been experiencing formidable obstacles in generating reasonably accurate forecasts of prices and supply of agricultural products. Braschler (1983) attributed part of the difficulty to the unprecedented exogenous shocks (e.g., oil embargo and energy shortages) which led the U.S. economy to gradually shift from relative stability to instability during the 1970's.

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[2] The effects of advertising on consumer demand is empirically tested in Ward and Myers (1979).

In the case of the U.S. livestock sector, the challenge in constructing forecasting and policy models arises not only from the concern to consider the potential instabilities due to exogenous shocks, but also from the concern to achieve both "local" and "global" approximation accuracy of model structure (Johnson, 1981). The concern to achieve global approximation accuracy has become of more particular relevance especially when there has been a structural change in the sector of interest. In this case, the structural shifts in the economic relationships of interest have to be accommodated and tracked by the policy and forecasting models.

Previous empirical attempts to detect structural change in the U.S. meat demand and supply have employed both simple and more complex model specifications and estimation procedures. The results of previous studies provide different conclusions regarding the significance, type, and timing of the hypothesized structural change in meat demand.

In particular, time series demand models designed to accommodate structural change by allowing structural parameters to vary over time provided interesting results. Tomek (1965) found some changes in the demand parameters for beef, pork, and chicken between the period 1949-1956 and 1957-1964. Another study conducted using a different time period found only small variations in meat demand between the period 1964-1968 and 1969-1975 (Leuthold, et.al.,1977).

This is somewhat supported by a later study which argued that the perceived decline in red meat demand during the 1970's can be attributed to increases in the overall supply of meat substitutes, particularly chicken and turkey and that the tastes and preferences for the three major meats did not change during the post-war period. (Bullock and Trapp, 1980).

Using quarterly data from 1965 through 1979, Nyankori and Miller found evidence of structural change in the quarterly demand for beef and chicken during the 1970's, but not in the demand for pork and turkey during the same period. A significant change in the demand parameters for beef was found to have occured in the first quarter of 1976. Nyankori and Miller (1982) used linear spline functions in their analysis, hence, allowing only for abrupt parameter change during the specific point in time.

Chavas (1983), by using a Kalman filter specification allowed a more gradual change in the demand parameters of beef, pork, and poultry. Using annual data from 1950 through 1979, significant parameter change in the demand for beef and poultry were detected in the 1970's relative to the 1950-1970 period. Chavas found no structural change in the demand for pork.

Moschini and Mielke (1984) tested the hypotheses of structural change in the demand for beef using quarterly data from 1966 through 1981. They found only weak evidence of structural change in beef demand and suggested that the recent decline in beef demand may only be due to changed market conditions and is, therefore, of a reversible nature.

Braschler (1983), on the other hand, provided evidence of significant structural change in the demand for both beef and pork. Using a switching regression model that allows abrupt changes in demand parameters, significant shift in the case of pork demand was found to have occured in 1970. In particular, the retail price of pork was found to be less sensitive to changes in the supply of pork, beef and real income, but more sensitive to changes in the supply of broilers during the period 1970-1982 compared to the period 1950-1969.

Cornell (1983), on the other hand, rejected a constant parameter formulation for the retail demand of table beef, hamburger beef and broilers. Cornell found evidence of rising direct flexibilities in the case of table beef over the past several years.

Frank (1984) used a gradual switching regression model to test structural change in the quarterly demand for beef, chicken, and pork. Using data from the first quarter of 1970 through the third quarter of 1983, the study gave additional evidence of structural change in the retail demand for beef, chicken, and pork. In particular, a significant parameter change was found to have occured in the third quarter of 1975 and continued into the 1980's.

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Yeboah and Heady (1984) examined the changes in the structural characteristics and estimates of supply response parameters in U.S. hog production. They tested the hypothesis of a decline in the supply elasticities and its effects on the inter-year fluctuations on pork output and prices. By dividing the period of analysis into two (1940-1959 and 1960-1977), the authors obtained evidence on the magnitudes and directional shifts in the supply elasticities for hogs.

1.5 Approach in Testing and Estimating Structural Change in the Aggregate U.S. Demand for Meat

The present study extends previous research on structural change in the U.S. demand for meat. In particular, this paper explores the systematic use of several statistical procedures to minimize if not prevent the problems associated with ad hoc analysis of structural change. Specifically, the study uses a three-stage approach in investigating changes in the demand structure for beef, pork, broiler, and turkey meat. The approach is useful in detecting structural change as well as misspecification in the context of simple models.

Meat demand models were constructed in the context of developing an annual price forecasting model for livestock and poultry. On an annual basis, quantities of most meats in the market are predetermined given the lags in livestock production. Given the market level data and the predetermined quantities, the demand models are specified as inverse demand functions.[3] That is, real market price is specified as a function of per capita quantity of commodity in question, per capita quantity of substitutes and complements, and real per capita disposable income (prices and income deflated by CPI).

The first stage of the analysis involves the estimation of inverse demand functions using recursive least squares[4] for the period 1955-1985. In this stage, the recursive parameter estimates are used as a descriptive tool in determining the effects of individual observation in a sequential updating procedure. The pattern of the recursive estimates of coefficients of the inverse demand models are analyzed, taking note of particular trends and discontinuities. Plots of the recursive coefficients indicate the pattern of variation of individual parameters.

Statistical testing of parameter variation and specification errors constitutes the second stage of the analysis. In this stage, the statistics based on standardized recursive residuals introduced by Brown, Durbin, and Evans (1975) and those suggested by Dufour

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[3] The theory of inverse demand functions is discussed in Anderson (1980), Salvas-Bronsard (1977), and in Houck (1966).

[4] The details of the recursive least squares are discussed in Harvey (1981).

(1981) are used to test parameter variation and departures from the fitted functional form.

The third stage of the analysis involve respecifying the model to include the information regarding the timing of the structural break indicated by the recursive residual analysis. Also gradual shifts in demand parameters are tested by augmenting the model with trend shifter variables. Other methods of allowing the parameters to gradually vary over time are also used.

This "exploratory approach"[5] is argued to be more sensitive to a wide variety of instability patterns and capable of providing information on the type and timing of structural change. The procedure is related to the family of approaches that are used to detect departures from the assumption of a model such as the "residual analysis" suggested by Anscombe (1963), Zellner (1975), Belsley, Kuh and Welsch (1980), and the "diagnostic checking" in time series analysis suggested by Box and Jenkins (1969).[6]

Dufour contrasted the exploratory methodology with other approaches which he calls "overfitting" procedures. The latter, which some previous research on structural change have used, involve nesting a model into a more general model by adding parameters and assumptions and

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[5] See Dufour (1981).

[6] Dufour, J.M., "Recursive Stability Analysis", Journal of Econometrics, 19(1992), pp. 32.

testing the significance of the added parameters. This approach is appropriate and powerful when one has a priori information about a specific type of structural change. The power of the tests involved in these procedures, however, depend on the assumptions made regarding the more general model.[7]

While the latter procedures appear useful in testing structural change against specific alternatives, Dufour argues for procedures that are capable of providing information about the types and timing of the likely changes, without having to make many additional assumptions. In his proposed data analytic approach, which is applied in this study, the recursive residuals are used as the basic instrument for tracking possible points of discontinuity Given the properties of the basic statistics calculated from the recursive estimation process (e.g., standardized recursive residuals, changes in the regression coefficients), structural change are indicated by tendencies to either overpredict or underpredict, heterogeneity in the prediction performance of the model, and trends in the coefficient estimates. While power against a specific alternative is not achieved through this procedure, some power against a broader range of interesting alternatives is facilitated.

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[7] ibid, p.33.

For the purposes of this study, these two approaches are considered complementary procedures instead of substitutes. The exploratory approach is used to assess patterns of parameter instability in the linear regression models. Essentially, the model is first placed in jeopardy and formal statistical tests are conducted to assess changes in the regression parameters. The clues and information derived from the significance tests may then be combined with other information to modify the specification of the linear model and explicitly account for the parameter variation.

1.6 Incorporating Structural Change in U.S. Livestock Production in Modeling Livestock Supply Response

Significant structural change in U.S. livestock production has been largely due to innovations in mechanical, biological, and organizational technology used in production. There has been a significant trend toward specialized buildings for each phase of production with emphasis on more confinement of the animals and greater environmental control of all aspects of production. These innovations has altered the financial and costs structure of the producing units, increased output per farm, and brought about concentration and greater specialization in livestock production.[8] The greater specialization in U.S. livestock production has in turn changed the economic relationships and patterns of livestock supply response.

To incorporate some aspects of structural change that have occured in U.S. livestock production, the changes in technical and biological factors are considered in specifying livestock supply response. The basic procedure of constraining supply response by a priori information on biological relationships was introduced by Chavas and Johnson (1982) and Okyere (1982). Biological relationships such as birth, culling, replacement, maturing and marketing rates were directly reflected as a priori restrictions for the supply model. These restrictions enter as physical accounting relationships. Ratios are calculated for the flow to flow and flow to stock variables. For instance, data indicated by the physical accounting relationships in hog production were used to estimate ratios between gilts becoming sows, pigs becoming feeder pigs, and feeder pigs becoming slaughter hogs. The trends in the biological ratios are then used to constrain the supply response models.[9]

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[8] See Reimund, Martin, and Moore (1981); Hayenga, et. al., (1981); Van Arsdall and Nelson (1984).

[9] See Goungetas, B., S.R. Johnson, W. Okyere, A.N, Safyurtlu, "Simultaneous Equations and Unobservable or Proxy Variables," AAEA Econometrics Refreshers Course Handout, August, 1983.

1.7 Organization of the Study

Following the introduction is the review of the theoretical foundations of consumer and producer behavior in Chapter 2. Also, the theory of inverse demand functions and supply dynamics relevant in the livestock sector are discussed. Chapter 3 presents the model structure of the constant parameter base model and empirical results. Chapter 4 provides a review of methods of testing structural changes in economic relationships. Simple and more advanced methods of testing and estimating structural change are reviewed. Changes in the model specification to account for possible changes in parameters due to structural change are also presented. The empirical results of the testing of structural change and the reestimation of the base model are presented in Chapter 5. Empirical estimates based on alternative specifications of the model to account for structural change are presented. Chapter 6 presents the specification of U.S. hog supply response model. Selected models are used in simulation analysis to provide intermediate and long-run projections of livestock production and prices. Results of the simulation analysis and model validation are reported in Chapter 7. Summary and conclusions are presented in Chapter 8.

CHAPTER 2

THEORETICAL FOUNDATIONS OF CONSUMER DEMAND AND DYNAMIC SUPPLY RESPONSE ANALYSIS

The neoclassical theory of consumer and producer behavior provides a general theoretical framework for empirical analysis of commodity demand and supply structures. In the case of applied demand analysis, however, the static theory becomes inadequate as it fails to consider the implications of certain phenomena such as structural change, habit formation and random shocks which may result in changes in the behavioral relationships over time. Since these factors have important implications on the growth prospects and general performance of commodity markets, the theory needs to be extended to facilitate the consideration of such phenomena in empirical applications.[1]

This chapter briefly reviews such theoretical foundations. The basic outline is as follows. First, the static theory of consumer demand is briefly reviewed. Second, the theory of inverse demand that is most useful for applied demand analysis is discussed. Specific emphasis is given on the restrictions on inverse demands implied by constrained utility maximization. The duality of inverse and direct demands are shown. The analogue for inverse demands to the concept of income effect for direct demand developed by Anderson (1980) is also briefly reviewed.

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[1] See Pope, R., R. Green, and J. Eales (1980) for empirical testing of habit formation in U.S. demand for meat.

2.1 The Static Theory

Applied demand analysis over the last 30 years have systematically employed the neoclassical theory of consumer demand. The structure of consumer preferences and utility maximization has important implications on consumer demand. Representing consumer behavior, the structure of the preference function is assumed to possess certain properties, namely, completeness, reflexibity, transitivity, continuity, monotonicity and strict convexity.[1] Given these properties, the consumer's preference ordering is represented by a real valued function, viz., the utility function. These properties and the assumption that the consumer chooses that bundle of goods which gives the highest level of satisfaction relative to the other available bundles allows static consumer behavior to be analyzed and modeled within the context of a constrained maximization problem.

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[1] The meaning and implications of these properties for demand analysis are discussed in Deaton and Muellbauer (1980), and in other texts of demand theory, viz., Phlips (1974).

2.1.1 Utility Maximization

Let q_i and p_i be the quantity and price of good i and q be a vector of goods available to a consumer with some fixed income, Y. Let the consumer's preferences be represented by the function, u(q), which is twice continously differentiable, strictly increasing and strictly quasi-concave (Deaton and Mauellbauer, 1980; Varian, 1978). The consumer's allocation problem is to

$$\text{(2.1)} \qquad \text{Maximize} \quad U = u(q)$$
$$\text{subject to } p \times q = Y$$

where p represents the vector of prices corresponding to q. Using the implicit function theorem, the system of first order conditions from (2.1) gives the uncompensated or Marshallian demand functions in vectors as follows

$$\text{(2.2)} \qquad q = g(p,Y).$$

The direct demands, (2.2), follow the neoclassical restrictions on the nature of the demand relationship, namely, (i) Engel aggregation or adding-up restrictions, (ii) homogeneity of degree zero in p and Y, (iii) symmetry of the matrix of Slutsky substitution effects and (iv) negative semi-definiteness of the matrix of the Slutsky substitution effects. Each of these properties follows from the linearity of the budget constraint. The adding-up restriction require that the total value of each quantity vector must equal the fixed budget. Since the constraint in (2.2) is linear and homogeneous in p and Y, the necessary conditions for a maximum is the same for all multiples of p and Y. Thus, (2.2) is homogeneous of degree zero in p and Y.

The above discussion indicates that, in general, the static theory of consumer behavior provides some useful insight for the applied demand analyst. Following the theory, the demand for a commodity may be specified as a function of prices of all goods and income. Also, to achieve theoretical consistency, the demand function should satisfy the theoretical restrictions of homogeneity, symmetry and adding-up. Furthermore, in order for an ad-hoc specification of demand to be consistent with an identifiable utility function, the analyst can impose the theoretical restrictions.

The characteristics of the direct demand functions in terms of elasticities also provide useful insights to the applied demand analyst. The price elasticity (uncompensated) can be estimated as follows:

$$(2.3) \qquad e_{ij} = g^{i}_{j}\ (p,Y)\ (p_j\ /g^{i}\ ),$$

where g^{i}_{j} is the partial derivative of g^{i} with respect to p_j.

The total expenditure elasticity is estimated as:

$$(2.4) \qquad n_i = g^i_Y(p,Y)\ (Y/g^i),$$

where g^i_Y is the partial derivative of g^i with respect to Y. Following the theoretical restrictions of the demand functions mentioned above, these elasticities possess certain properties, namely,[2]

$$(2.5) \qquad \sum_j (e_{ij}) = -n_i,$$

$$(2.6) \qquad \sum_i (w_i\ e_{ij}) = -w_j,$$

$$(2.7) \qquad \sum_i (w_i n_i) = 1$$

where $w_i = p_i q_i / Y$.

Property (2.5) follows from the homogeneity restriction while (2.6) and (2.7) follow from the adding-up restriction. The compensated price elasticities can be derived by specifying the cost function as follows:

$$(2.8) \qquad C(p,u) = \min\ (Y \mid p \times q < Y \ \text{and}\ U(q) > u\ ).$$

The cost function, $C(\ )$, is linearly homogeneous and both continous, nondecreasing and concave in p and increasing in u (Varian, 1978). The first partial derivatives of the cost function with respect to price gives the compensated demand function defined as

(2.9) $$q_i = g^{i*}(p,u) = C_i(p,u).$$

The Slutsky substitution effects are derived from the second partial derivatives with respect to price. They are defined as

(2.10) $$c_{ij}(p,u) = g^{i*}_{j}.$$

The compensated elasticities are then defined as

(2.11) $$e^*_{ij} = g^{i*}_{j}\ (p_j/g^{i*}).$$

From the homogeneity restriction, these elasticities follow the condition

(2.12) $$\sum_j (e^*_{ij}) = 0.$$

The property of concavity of the cost function leads to the negative semidefiniteness characteristic of the Slutsky matrix which in turn, implies the law of demand stated as

$$e^*_{ii} < 0.$$

The compensated elasticities can be defined in terms of uncompensated elasticities based on the Slutsky equation as follows:

(2.13) $$e^{*}_{ij} = e_{ij} + n_i w_j$$

2.2 The Theory of Inverse Demand for Applied Demand Analysis[2]

The discussion on the theory of inverse demand is based on the work of Anderson (1980). The relevance of inverse demand theory in applied demand analysis for some food commodities has been recognized. However, there has been limited applications of the theory in applied work. Examples of empirical studies which specified and estimated demand with prices as functions of quantities are as follows: Salvas-Bronsard, et.al.,(1977); Christiansen and Manser, (1977); Barnett, (1977); Shonkwiler and Taylor (1984); Braschler (1983), Cornell (1983), Dahlgran (1986). This section briefly outlines the theory of inverse demand that is most useful to empirical demand analysis.

The theoretical restrictions for inverse demand that are analogous to those of direct demand follow from the standard neoclassical assumptions regarding the structure of the preference function. Inverse demand is specified with

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[2] See Anderson (1980). Salvas-Bronsard, et. al., (1977) discussed the properties on inverse demand functions in the context of a demand system.

price as a function of quantities and total expenditure; that is

(2.14) $$p_i = f^{+1}(q,Y)$$

where $f^{+1}(q,Y)$ is linear and homogenous in Y.

The "quantity elasticity" or "flexibility" of good i with respect to good j can be defined as follows

(2.15) $$f_{ij} = f_j^{+1}(q,Y)\ (q_j/f^{+1})$$

where f_j^{+1} is the partial derivative with respect to q_j.

Quantitity elasticity or flexibility is the analogue for inverse demand of price elasticity in direct demand. It indicates the change in the price i necessary to induce a marginal change in consumer's consumption of good j.

A relationship between price elasticities and quantity flexibility was first developed by Houck (1965) in the following form

(2.16) $$e_{ii} = 1/f_{ii}$$

Houck (1965) showed that under general conditions, the inverse of the direct flexibility is equal to the lower absolute limit of the direct price elasticity. The strength of the cross effects of substitutes and complements will determine the size of the difference between these two va

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values. In particular, if all the cross effects are zero, the reciprocal of the direct price flexibility is equivalent to the direct flexibility.

Anderson (1980) developed the analogue of total expenditure elasticities in inverse demands. Within the context of inverse demand analysis, Anderson asked the question: "how much will price i change in response to a proportionate increase in the quantity of all commodities".

This question looks at the behavior of prices as the scale of the commodity vector along a ray from the origin is changed. In order to answer this question, Anderson (1980) formalized the notion for marginal increases in the scale of consumption by defining the "scale elasticity" and deriving the restrictions relating "quantity elasticity" and "scale elasticity". The latter was shown to be the analogue of total expenditure elasticity.

Following Anderson's notation, the inverse demand function is defined as

$$(2.17) \qquad p_i = f_i(kq^*) = g^i(k, q^*)$$

The "scale elasticity" of good i is written as

$$(2.18) \qquad s_i = g^i{}_o(k, q^*)\,(k/g^i)$$

where $g^i{}_o(k,q^*)$ is the derivative of g^i with respect to k.

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It is also shown by Anderson that the sum of the budget share weighted quantity elasticities with respect to x_j is equivalent to the negative of the budget share of good j.

This is shown by defining the budget constraint as

$$(2.19) \qquad 1 = \sum_i f^i(q)q_i$$

By taking the derivative with respect to q_j,

$$(2.20) \qquad 0 = \sum_i f^i{}_j \, q_i + f^j = \sum_i f^i{}_j (q_j/f^i) f^i q_i + f^j q^i{}_j$$

or

$$(2.21) \qquad \sum_i f_{ij} \, w_i = -w_j$$

(2.21) is the analogue of the Cournot aggregation condition. The analogue to the Engel aggregation is derived by taking the sum of (2.21) as follows

$$(2.22) \qquad \sum_i w_i \sum_j f_{ij} = - \sum_j w_j$$

Given (2.12) and $\Sigma \, w_j = 1$, the analogue of restriction (2.5) is derived as

$$(2.23) \qquad \sum_i s_i = -1$$

"Scale" and "quantity" elasticities defined above correspond to the concepts of uncompensated elasticities relevant for inverse demands. The compensated "quantity elasticity" is derived from the transformation function which is dual to the cost function. The transformation function, $T(q,u)$, is shown to satisfy the following condition:

$$(2.26) \qquad U(q^*/T(q^*,u^*)) = u^*$$

for all attainable value of q^* and u^*. The transformation function indicates how much a certain consumption vector must be divided to bring the consumer on another indifference curve. This function is non-decreasing, linear homogenous and concave in q and decreasing in u. By taking the derivative with respect to goods, the constant utility or "compensated" inverse demand function is derived

$$(2.27) \qquad p_i = f^{i*}(q,u) = T_i(q,u)$$

where T_i is the partial derivative with respect to q_i. These inverse demand functions indicate the levels of normalized prices that induce consumers to choose a consumption bundle that is along a ray passing through q with an associated utility level u. The second partial derivatives of the transformation function, T, (i.e, the first partial derivative of f^{i*}) provide the Antonelli substitution effects which indicate the amounts normalized prices change as a result of a marginal change in the reference consumption, q_j, while keeping the consumer on the same indifference curve. The constant utility (compensated) "quantity elasticities" or flexibilities can then be defined as

(2.28) $$f^*_{ij} = f^{i*}_j \,(q_j / f^{i*}).$$

Since the transformation function is homogenous of degree one in q, f^{i*} is homogenous of degree zero in q. Hence, applying the Euler's theorem to (2.28) gives the following restriction

(2.29) $$\sum_j f^*_{ij} = 0$$

Note that (2.29) is analogous to (2.12). Also, following the properties of the transformation function, the matrix of Antonelli effects is negative semidefinite. This implies

(2.30) $$f^*_{ii} < 0$$

which define the "law of inverse demand".

The understanding of the "implicit compensation scheme" and the derivation of the analogue of the Slutsky equation aids the interpretation of the compensated quantity elasticities in applied demand analysis.

To achieve theoretical consistency, specified direct demand equations in a complete system should be homogenous, symmetric and add-up. To achieve this, one could derive the system of demand equations from a specified utility function. This approach results in a loss of generality due to the choice of a particular utility function. On the other hand, any ad-hoc demand structure is assured to correspond to an identifiable utility function if the theoretical restrictions are imposed (Deaton and Muellbauer, 1980). This approach usually requires the use of some sophisticated econometric procedures.

When only a number of commodities are of main interest in the demand study, the analyst usually assumes a separable utility function. The condition of strong separability is satisfied if the marginal rate of substitution between goods i and j, which belong to commodity group r and t respectively, is independent of the consumption of commodities in any other group, l. The separability condition require that the consumers attempts to maximize utility in two stages. In the first stage, the consumer allocates his/her expenditures between l separable commodity groups. In the second stage, expenditures in one group are divided among individual commodity expenditures. (George and

King, 1971). Since marginal utilities are difficult to estimate in actual practice, the groups of commodities are often arbitrarily selected. DeJanvry's (1966) results indicate that meat could then be considered as one separable group. If structure have changed, meat may no longer be separable.

As others have recognized, there remains a gap between theory and empirical analysis of demand. The gap is a result of problems and difficulty in developing and imposing appropriate theoretical restrictions in the context of full market demand systems. For example, the Slutsky condition derived from the individual demand theory does not hold for market demand without assuming strong separability condition (Safyurtlu and Johnson, 1985).

2.3 Theoretical Extensions to Analyze Structural Change in Consumer Demand

The basic simplifying assumption in the neoclassical demand theory outlined above is the constancy of preferences of individual consumers. The length of the period in which the utility function is defined is such that it is long enough to allow the consumer to satisfy his(her) preferences regarding certain varieties of goods but not too long so that his(her) tastes might change. That is, consumer preferences are assumed to be given in the analysis employing the static theory. Although this assumption makes applied demand analysis manageable, its limiting effect has been recognized. Attempts have been made to consider possible changes in consumer preferences. Phlips (1974) presented a theory of intertemporal utility functions which allows for changing preferences. When consumer preferences are allowed to change in demand analysis, the system of demand will also change. That is, the change in the structure of consumer preferences will lead to a change in the consumer's utility function which in turn lead to a change in the structure of the demand function.

Green (1978) identified some factors which might affect preferences of consumers. The effect of such factors as advertising, choices of other consumers and long-run changes in prices on the structure of consumer preferences were discussed. Cornell (1983) discussed the effects of these factors on the consumers' retail demand for meat. The effect of advertising on consumer preferences is based on the notion that the latter is influenced by information available to the consumer. Information on the characteristics of goods influence the choice of an individual consumer (Lancaster, 1966).

Another limiting assumption within the context of static demand theory relates to the presumed instantaneous adjustment to new levels of equilibrium when there is a change in prices or income variables. It has been recognized that consumers respond and adjust to such price and income changes in a gradual manner over time due to habit formation and dynamic characteristics of consumer behavior.

Attempts have been made to include the effects of habit formation in analyzing consumer demand. The common approaches involve the inclusion of dynamic aspects into the utility function or directly into the demand functions. The latter approach have been applied more than the former in applied demand analysis. Among the common methods under this approach include the specification of a time trend in the demand equation, use of a distributed lag model, use of a cob-web model, and the use of first differences of variables. Among the different ad-hoc models, the partial adjustment model developed by Houthakker and Taylor (1966) have been employed in empirical demand analysis. These models specify demand as a function of not only prices and income, but also of lagged values of certain variables.

2.4 Demand Irreversibility

Demand irreversibility is based on the notion that consumers' tastes may change in the long-run due to habit formation. An irreversible demand model was first tested by Farrell (1952). The model distinguished between rising and falling stages in the income and price variables. Irreversibility in the demand for beef was tested by

Goodwin, et.al., (1968). Possible irreversible behavior in beef demand is a result of the existence of consumption habits, the cyclical pattern in prices and consumption and the identified distinction between short-run and long-run demand response. Habit formation is considered to not only prohibit immediate price-quantity adjustments, but also may affect other patterns of consumption behavior which causes shifts in the parameters associated with other explanatory variables. Pope, et.al. (1980) developed the theoretical basis for possible changes in elasticities due to habit formation.

Goodwin, et.al. (1968) provided some empirical evidence on the irreversibility in demand for beef. Their study provided separate estimates of short-run and long-run elasticities for both decreasing and increasing consumption of beef. In the short-run, the direct price elasticities were found to be lower (more inelastic) in periods of declining consumption. This is consistent with the hypothesis that consumers change their consumption level by less during period of increasing price than during the period of declining price. Also, it was found that the income elasticities were larger during periods where prices decline. The stronger response to changes in income during phases of declining prices was considered a result of the existence of a broader range of quantities included in the inelastic portion of the demand curve over time. Another interesting result from the Goodwin study is the tendency of the price and income elasticities to decline over time. This phenomenon was explained to result from the decreasing share of income spent on beef over time as income rises. The coefficient of adjustment was also estimated and estimation results indicated an immediate adjustment of consumption after a decline in price but a lagged adjustment of consumption was found after a price increase. The lagged consumption response after a rise in price was hypothesized to result from the persistence of habits that were formed before the price increase. This phenomena was considered to characterize irreversibility in the demand for beef.

2.5 Theoretical Foundations in Dynamic Supply Response Analysis

For the purpose of the present study, the distinction made by Cochrane (1955) between supply function and supply response will be adopted. A supply function indicates how the amount of a commodity offered for sale changes with price during a given period under ceteris paribus condition. A supply response indicates how the amount of a commodity offered for sale changes with price when all the other factors are allowed to change. The latter concept is more useful in predicting the impact of changes in price on the quantity offered for sale in the aggregate sector level.

The existing theory of supply dynamics has been widely appplied in empirical analysis of supply response of agricultural commodities. Most empirical studies have employed econometric models which attempt to capture the dynamic behavior in supply response. One aspect of the dynamic behavior which has gained attention both in theory and in applied analysis is the price expectations formation of producers and how it affects supply. Also, models usually differentiate between desired and actual levels of output. The adjustment toward the desired output level is estimated using a distributed lag specification. The latter is usually based on Nerlove's formulation of adaptive expectations hypothesis which assumes that in each period, the producer revises his expected price in proportion to the difference between the last period's price and the last period's expected price. In this model, the producer's long-run expected price is specified as a weighted moving average of lagged prices with the weights declining over time (i.e., a geometric distributed lag).

2.6 Summary

The neoclassical economic theory provides a general framework for supply and demand analysis. However, the static theory is limited for certain aspects of empirical

analysis. Extensions of the theory are needed to analyze habit formation and structural change in demand. The implications of changes in preferences in analyzing consumer demand are considered in extensions in the theory such as in the theory of intertemporal utility functions.
Habit formation and other dynamic characteristics of consumer behavior are considered in ad-hoc specifications of demand function such as in Nerlove's partial adjustment model and in stock adjustment model developed by Houthakker and Taylor.

The theory of inverse demand provides a useful framework in analyzing demand for meat commodities. The demand parameter measures the responsiveness of a commodity price to a change in quantity supplied. The theoretical restrictions on inverse demand function are shown by Anderson (1980) to be analogous to those of direct demand function implied by constrained utility maximization.
Estimated inverse demand function for beef, pork, turkeys, and broilers are presented in the following chapter.
The specification of constant price models estimated in the next chapter is based on the theory of inverse demand discussed in this chapter. Estimates of "quantity elasticities" or flexibilities are presented .

CHAPTER 3

SPECIFICATION OF CONSTANT PARAMETER (BASE) MODEL OF U.S. LIVESTOCK PRODUCTION AND PRICES AND EMPIRICAL RESULTS

The general method employed in the estimation of the constant parameter base model of the U.S. livestock production and prices follows from the approach suggested by and Johnson and Rausser (1977) which involves three major stages. First, the system under consideration is studied and the structural relationships identified and delineated. The second stage involves the representation of the identified relationships in a quantitative framework. This stage includes the specification, estimation, verification, validation, and revision of the model structure. The third stage involves the use of the estimated model in the context of policy analysis and forecasting.

Verification involves the evaluation of individual equations based on regression diagnostics and comparison of parameter estimates with previous empirical evidence. The validation stage of the model construction involves the evaluation of both individual equations and blocks of equations. Initial validation of the model is carried out by using the model to simulate the historical period. Separate blocks of equations are simulated in order to locate sources of unstable behavior in the system. The performance of the livestock model as an entire system is also evaluated using absolute and relative accuracy performance measures.

3.1 Structure of the Base Model

3.1.1 Livestock and Poultry Production

This section presents the structure of the base livestock supply and demand model. The base model of domestic livestock and poultry consists of 20 behavioral equations and 15 definitional equations covering five major livestock and poultry products: beef, pork, broilers, turkeys and eggs. The structure of the model is presented in Figure 3.1.

The livestock and poultry model is an annual model. The annual specification is a result of the underlying objectives of the MSU Agriculture Model to identify the dynamics of adjustment in the longer run and to provide intermediate and long-run projections of quantities and prices for the commodities included in the model. The specification and design of the model therefore do not measure short-run and seasonal variations within a year.

The equations in the model are specified and estimated using aggregate national data. Hence, the model specification does not estimate regional or state differences in production systems such as differences in

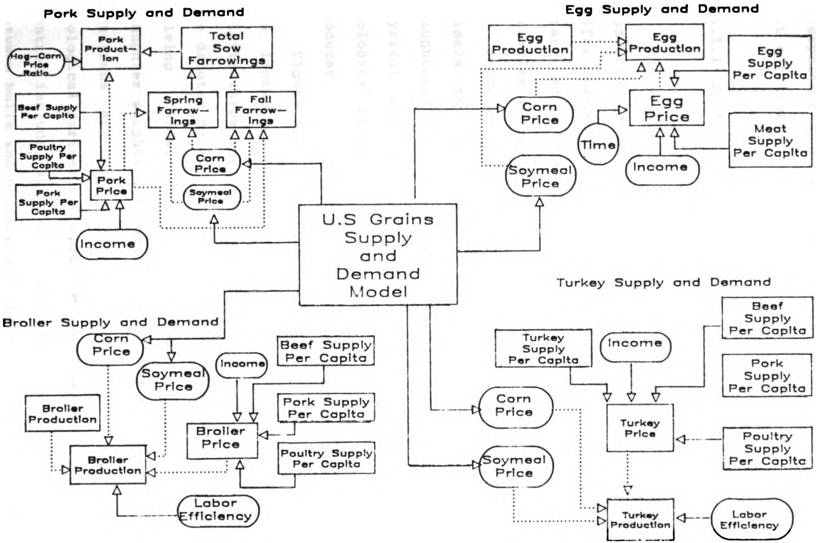


Figure 3.1 Pork, Broiler, Turkey, Egg Supply And Demand Model

Dotted lines indicate lags

enterprise combinations, size of operations, and relative cost structures.

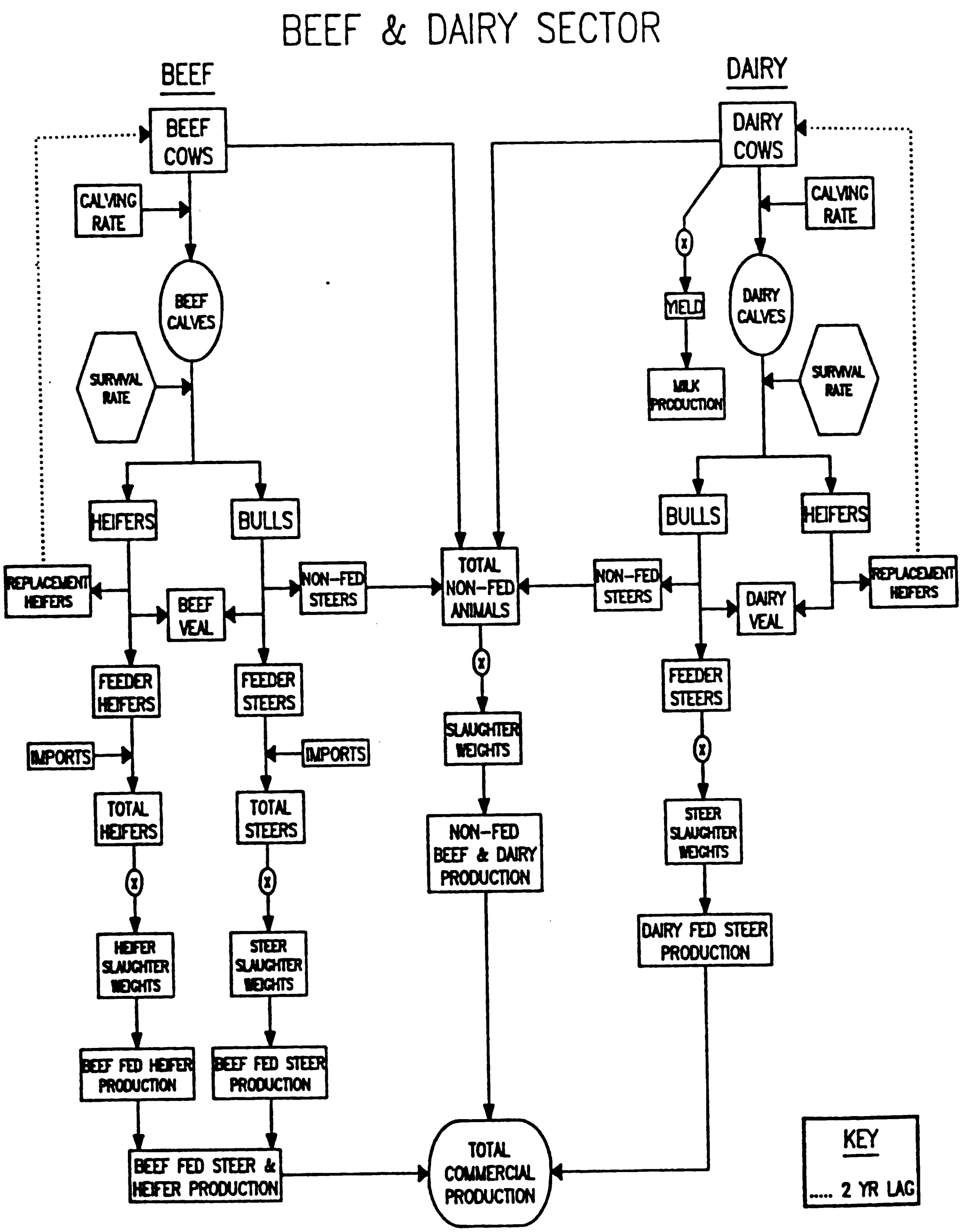
3.1.1.1 Beef Production

The variables which are endogenous to the beef production model include beef cow inventory, steer and heifer slaughter and cow and bull slaughter. Beef supply is determined in the model by specifying producer decision variables and physical response variables.

Producer decision variables include the number of animals to sell, the weight at which an animal is slaughtered and the rate of herd expansion or contraction. Physical response variables are determined mainly by biological factors which are outside the control of the producer.

Figure 3.2 shows the structure of the beef model and the linkages between the beef and dairy sectors. Relationships which are estimated based on economic factors are denoted by an asterisk (*). Estimated equations for calving rates, breed-feed-slaughter decisions and the slaughter weights are included. Separate slaughter weight equations are estimated for steers and heifers. The biological parameters specified as independent of producer control include survival rates, the distribution of calves between bulls and heifers and the meat yield per carcass.

Figure 3.2


BEEF & DAIRY SECTOR
BEEF
DAIRY
BEEF COWS
CALVING RATE
BEEF CALVES
SURVIVAL RATE
HEIFERS
BULLS
REPLACEMENT HEIFERS
BEEF VEAL
NON-FED STEERS
FEEDER HEIFERS
FEEDER STEERS
IMPORTS
IMPORTS
TOTAL HEIFERS
TOTAL STEERS
X
X
HEIFER SLAUGHTER WEIGHTS
STEER SLAUGHTER WEIGHTS
BEEF FED HEIFER PRODUCTION
BEEF FED STEER PRODUCTION
BEEF FED STEER & HEIFER PRODUCTION
TOTAL NON-FED ANIMALS
X
SLAUGHTER WEIGHTS
NON-FED BEEF & DAIRY PRODUCTION
TOTAL COMMERCIAL PRODUCTION
DAIRY COWS
CALVING RATE
X
YIELD
MILK PRODUCTION
DAIRY CALVES
SURVIVAL RATE
BULLS
HEIFERS
NON-FED STEERS
DAIRY VEAL
REPLACEMENT HEIFERS
FEEDER STEERS
X
STEER SLAUGHTER WEIGHTS
DAIRY FED STEER PRODUCTION
KEY
..... 2 YR LAG

Beef cow numbers are estimated as the sum of the cow herd and replacements less the number of culls and deaths. Cull cows and non-fed steers both become part of the non-fed beef category. Non-fed beef production is determined from the number of animals in this category times the slaughter weight per animal. The slaughter weight for non-fed beef is estimated for all non-fed beef and makes no distinction between cows and steers. Dairy cull cows and non-fed dairy steers are also included in the non-fed category. Total commercial meat production is the sum of fed beef steer and heifer production, non-fed beef and dairy production, and dairy fed steer production.

Beef Cow Numbers (BFCOWT):

$$BFCOWT = B_0 + B_1 * BFCOWT(t-1) + B_2 * FCVP(t-1) + B_3 * FCVP(t-2) + B_4 * FCVP(t-3)$$

FCVP = Feeder calf prices, $/cwt.

BFCOWT = Beef cow numbers, January 1, (1000 head)

Beef Heifer Replacements (BFHEIF):

$$BFHEIF = B_0 + B_1 * BFHEIF(t-1) + B_2 * BCP(t-1) + B_3 * BCP(t-2)$$

where

BCP = BFCALF/CPIT

BFHEIF = Beef Heifer Replacements, January 1 (1000 head)

BFCALF = Beef Calf Price, \$/cwt. (Kansas City)

CPIT = Consumer Price Index, 1967 = 1.0

Steer Slaughter Weight (STWT):

$$STWT = B_0 + B_1 * TIME + B_2 * RATIO(t-1)$$

where

RATIO(-1) =(FBEFPT/CORNPT)(-1)

STWT = Average Steer Slaughter Weight, lbs.

TIME = 1983= 83, 1982=82,...etc.

FBEFPT = Omaha Choice Steer price, \$/cwt.

CORNPT = U.S. Average Corn price received by farmers, \$/bu.

Heifer Slaughter Weight (HFSW):

$$HFSW = B_0 + B_1 * TIME + B_2 * RATIO(t-1)$$

where

RATIO = FBEFPT/CPIT

HFSW = Average Heifer Slaughter Weight,lbs.

TIME = 1983=83, 1982=82,... etc.

FBEFPT = Omaha Choice Steer price, \$/cwt.

CORNPT = U.S. Average Corn price received by farmers, \$/bu.

3.1.1.2 Pork Production

The supply structure for pork is determined largely by the relationship between hog and feed prices. Pork production is determined based on the sows farrowing in the previous fall and sows farrowing in the spring of the current year, last period's pork production and ratio of hog price to corn and soymeal prices.

Supply estimation starts with the estimates of spring and fall sows farrowing. The fall farrowing equation is determined by the most recent spring farrowing, corn and soymeal prices and hog price. A variable to represent the closing of the spring farrowing versus fall farrowing levels starting in 1975 is also included. The spring farrowing equation reflects the role of partial adjustment based upon the December 1 inventory of sows and the changes in the profitability of hog production. Variations in pork production is explained in the model by the variations in sow farrowing and the changes in the hog-corn and hog-soybean meal price ratios.

<u>Sow Farrowing in the Fall (SOWFFT)</u>:

$$SOWFFT = B_0 + B_1 * SOWFST + B_2 * PPORK(t-1) + B_3 * CORNP(t-1) + B_4 * SOYMP(t-1) + B_5 * D75 * SOWFST$$

where

PPORK = PORKPT/CPIT

CORNP = CORNPT/CPIT

SOYMP = SOYMPT/CPIT

SOWFST = Sow farrowing in spring, 1000 head

PORKPT = Price of barrows and gilts, 7 markets $/cwt.

CORNPT = U.S. Average Corn price received by farmers, $/bu.

SOYMPT = U.S. Average Soymeal price received by farmers, $/cwt.

CPIT = Consumer price index, 1967 = 1.0

D75*SOWFST = D75 is equal to 60, 61, 62,... for period prior 1975 and equal to 75 for the period starting 1975 to 1984. This accounts for the leveling of fall farrowings with spring farrowings starting in 1975.

<u>Sow farrowing in the spring (SOWFST)</u>:

$$SOWFST = B_0 + B_1 * SOWFST(t-1) + B_2 * CORNP(t-1) + B_3 * CORNP(t-2) + B_4 * SOYMP(t-1) + B_5 * SOYMP(t-2) + B_6 * PPORK(t-1)$$

<u>Pork Production (PORKQT)</u>:

$$PORKQT = B_0 + B_1 * PORKQT(t-1) + B_2 * SOWS + B_3 * PKCRR + B_4 * PKSMPR$$

where

PKCRR = PORKPT(t-1)/CORNPT(t-2)

PKSMPR = PORKPT(t-1)/SOYMPT(t-2)

PORKQT = Pork production, million lbs., carcass weight

SOWS = SOWFFT(t-1) + SOWFST

3.1.1.3 <u>Poultry Production</u>

The poultry sector includes separate equations for broilers, turkeys and eggs. This poultry sector is included in the model in order to provide a complete framework for determining feed demand of the entire livestock sector.

An annual specification for the poultry sector is inadequate to model poultry production response. Producers frequently make adjustments within a year in response to prices and costs or expectations about future market conditions. It only takes about 8 weeks to produce a batch of broilers while about 2 flocks of turkeys may be grown within one year. Hence a model designed to capture the year- to-year production response is not as clearly applicable for the poultry sector as for the cattle and hog industries. To the extent that within year adjustments may deviate from the year-to-year production patterns, the relationship between average prices in the previous year and the current year's production may be imperfect.

The inadequacy of an annual specification for poultry was recognized, yet maintained in the current model specification to achieve consistency in the time period with the rest of the livestock sector. The specification appears reasonable in determining feed demand based on the current characteristics of the industry.

The results of the current poultry sector model should, however, be interpreted with caution considering the limitations imposed by time aggregation problems. Future versions of the model might consider a quarterly model specification. Likewise, a procedure to integrate a quarterly model with an annual model would have to be developed.

The supply of the poultry commodities is determined in the model by the lagged product and feed prices, lagged production, and a productivity shifter. The latter is represented by the labor efficiency variable as a proxy for a measure of the net effect of technological change. An increase in the average productivity of labor has contributed significantly in the growth of the poultry industry. Man hours required per 1000 broilers has declined from 26 in 1965 to 15 in 1969 as a result of increased mechanization and more efficient layouts (Ensminger, 1980). Due to the high correlation between the labor efficiency time series for broilers, turkeys and eggs, and in order to reduce the number of exogenous variables in the model, the labor efficiency for broilers was used as a proxy for technological change for the three poultry products. Whether labor productivity will continue as an important factor in determining the growth of the poultry industry will depend on the likely share of labor in future poultry production. Mechanical and biological technology and management systems also resulted in better feed conversion, higher production per bird, and reduced mortality. Future model reestimations may need to consider the role of these productivity factors in determining trends in poultry supply.

<u>Broiler Production (CHIKQT)</u>:

$$\begin{aligned} CHIKQT = {} & B_0 + B_1 * CHIKQT(t-1) + B_2 * CHPT(t-1) \\ & + B_3 * CORNP(t-1) + B_4 * SOYMP(t-1) \\ & + B_5 * LHFW \end{aligned}$$

where

CHPT = CHIKPT/CPIT

LHFW = CHIKLE * FWAGET

CHIKQT = broiler production, ready-to-cook, million lbs.

CHIKPT = average broiler farm price, live weight, cents/lb.

CHIKLE = hours of labor per cwt. of broiler production

FWAGET = farm wage rate, $/hr.

<u>Turkey Production (TURKQT)</u>:

$$TURKQT = B_0 + B_1 * TURKQT(t-1) + B_2 * TKPT(t-1) + B_3 * CORNP(t-2) + B_4 * SOYMP(t-2) + B_5 * LHFW$$

where

TKPT = TURKPT/ CPIT

TURKQT = turkey production, ready-to-cook, million lbs.

TURKPT = average turkey farm price, live weight, cents/lb.

<u>Egg production (EGGQT)</u>:

$$EGGQT = B_0 + B_1 * EGGQT(t-1) + B_2 * EGP(t-1) + B_3 * CORNP(t-1) + B_4 * LHFW$$

where

EGP = EGGPT/CPIT

EGGQT = egg production, million dozen

EGGPT = egg average farm price, cents/dozen

3.1.2 Livestock and Poultry Demand

This section presents the specification of the livestock and poultry demand model. Before the presentation of the model equations, a justification for a price dependent demand model is provided.

The structure of the U.S. market for animal products in aggregate provides the justification for a price dependent formulation of the annual demand models estimated in this study. In the case of beef and pork, consumption is determined primarily by the quantities that are marketed. The magnitude of changes in stocks of these animal products is small relative to production; also, exports and imports of these products are small relative to production. Although the decision to feed animals to heavier slaughter weights may be affected by the current price, the decision to produce the animals was made in some previous period. Hence, the quantities of animal products available for consumption are largely predetermined in the current period and prices adjusts to clear the market.

It is noted that this specification of demand relationship may not hold for poultry products due to the shorter production cycle involved. However, a similar formulation was applied for poultry in this study in order to achieve consistency in the overall estimation of the annual demand for animal products. The following specification of the U.S. demand for livestock and poultry is therefore adopted in this study:

$$P(i) = g\ (\ Q(i),\ Q(j),\ Y,\ Z\ )$$

where

$P(i)$ = price of the ith good

$Q(i)$ = quantity of the ith good available for consumption, per capita

$Q(j)$ = quantity of a substitute good available for consumption, per capita

Y = disposable income, per capita

Z = other shifter variables.

3.1.2.1 Beef Inverse Demand

The beef demand model includes three equations for Omaha Choice steer prices, commercial cow prices and import demand for non-fed beef. The following equations are formulated for the beef demand model:

Choice Steer Price (FBEFPT):

$$
\begin{aligned}
(FBEFPT/CPIT) = B_0 &+ B_1 * BFPC + B_2 * PKPC + B_3 * DINC \\
&+ B_4 * DV73ON + B_5 * DVT73 \\
&+ B_6 * DV80ON + B_7 * DVT80
\end{aligned}
$$

where

BFPC = (FBEFQT + NFBFQT + NFBIMT)/POPUS

PKPC = (PORKQT + PKIM - PKEX)/POPUS

DINC = DPCIT/CPIT

FBEFPT = Choice Steer Price at Omaha, \$/cwt.

FBEFQT = Steer and Heifer slaughter, carcass weight, million lbs.

NFBFQT = Cow and Bull slaughter, carcass weight, million lbs.

NFBIMT = Non-fed beef imports, carcass weight, million lbs.

PORKQT = Pork production, carcass weight, million lbs.

PKIM = Pork imports, million lbs.

PKEX = Pork exports, million lbs.

CHIKQT = Chicken production, ready-to-cook, million lbs.

TURKQT = Turkey production, ready-to-cook, million lbs.

POPUS = Total U.S. population, millions

CPIT = Consumer Price Index, 1967 = 1.0

DV73ON = 1.0 for Time 1973-1984, 0 otherwise

DVT73 = Time * DV73ON

DV80ON = 1.0 FOR TIME 1980-1985, 0 otherwise

DVT80 = Time * DV80ON where Time = 55, 56, 57, ..., 85

The annual average price of choice steers at Omaha was chosen as the proxy variable for the general price level of cattle. This choice is based upon the importance of the Omaha market for cattle, market location relative to production and consistency of price differentials with other markets and availability of consistent time series data. While shifts in per capita production of steer and heifer beef have caused most of the variation in fed cattle prices, other variables are expected to have significant impacts also. Supplies of cow and bull beef including net imports are expected to influence choice steer prices. This is because hamburger and other processed beef compete with carcass beef and about a fourth of the steer and heifer carcass is usually used for hamburgers. For similar reasons, supplies of steer and heifer beef is expected to influence cow prices.

Also, pork and poultry are considered as competitors for the consumer meat dollar. Likewise, consumer income is expected to influence cattle prices. The consumer price index was chosen as a deflator for both income and the price variables.

Commercial Cow Prices (COWP):

$$BFCOWP/CPIT = B_0 + B_1 * QNFB + B_2 * QFBEEF + B_3 * QNONBF + B_4 * DINC + B_5 * DV73ON + B_6 * DVT73 + B_7 * DV80ON + B_8 * DVT80$$

where

COWP = BFCOWP/CPIT

QNFB = NFBFQT/POPUS

QFBEEF = FBEFQT/POPUS

QNONBF = (PORKQT+CHIKQT+TURKQT)/POPUS

BFCOWP = Commercial Beef cow price, Omaha, $/cwt.

Import Demand for Beef (NFBIMT):

Import demand for non-fed beef is determined by the import quotas specified in the counter-cyclical import law. The import law is imposed in order to regulate fluctuations in beef prices. It allows higher imports of beef during period of low domestic supplies and high consumer prices conversely, allowed beef imports are reduced in years of high domestic beef supplies and low prices. The import quota is explicitly included in the structure of the model according to the legislated formula. Since 1980, the level of U.S. beef imports has been determined by applying the counter-cyclical meat import formula defined as follows (Simpson, 1982).

$$\text{Annual Quota} = \begin{array}{c}\text{Average}\\ \text{annual}\\ \text{imports}\\ \text{(1968-77)}\end{array} * \frac{\begin{array}{c}\text{3-yr. moving}\\ \text{average of}\\ \text{domestic production}\end{array}}{\begin{array}{c}\text{10-yr. average of}\\ \text{domestic production}\\ \text{(1968-77)}\end{array}} * \frac{\begin{array}{c}\text{5-yr.moving}\\ \text{average of}\\ \text{domestic cow}\\ \text{beef}\\ \text{production}\end{array}}{\begin{array}{c}\text{2-yr.moving}\\ \text{average of}\\ \text{domestic cow}\\ \text{beef}\\ \text{production}\end{array}}$$

In the model, non-fed beef imports are assumed to be equal to the beef import quota as determined by the counter-cyclical meat import formula. This implies that beef export supply of exporting countries is assumed to be completely elastic. That is, exporters are assumed to maximize their profits by exporting beef quantities according to the maximum levels determined through the counter-cyclical meat import law.

3.1.2.2 Pork Inverse Demand

The pork demand model include a single equation for the price of barrows and gilts represented by the following equation:

Price of Pork (PORKPT):

$$PORKPT/CPIT = B_0 + B_1 * PKPC + B_2 * BFPC + B_3 * POULPC + B_4 * DINC + B_5 * DV73ON + B_6 * DVT73 + B_7 * DV80ON + B_8 * DVT80$$

where

PPORK = PORKPT/CPIT

POUL = (CHIKQT+TURKQT)/POPUS

The farm price of pork (proxied by the price of barrows and gilts in 7 markets) is determined based on the pork quantity available for consumption, quantities of substitute meats and disposable income. The dummy variable has the same definition as those used in beef price equation.

3.1.2.3 Poultry

The poultry demand model include separate equations for broilers, turkeys and eggs. The price equation for each of the poultry products are given as follows:

Broiler Price (CHPT):

$$CHIKPT/CPIT = B_0 + B_1 * POULPC + B_2 * BFPC + B_3 * PKPC + B_4 * DINC$$

where

CHP = CHIKPT/CPIT

POULPC = CHIKQT/POPUS

<u>Turkey Price (TURKPT)</u>:

$$TURKPT/CPIT = B_0 + B_1 * POULPC + B_2 * BFPC + B_3 * PKPC + B_4 * DINC$$

where

TKP = TURKPT/CPIT

TURKPT = Turkey price received by farmers, cents/lb.

<u>Egg Price (EGGPT)</u>:

$$EGGPT/CPIT = B_0 + B_1 * EGPC + B_2 * MEATPC + B_3 * DINC + B_4 * TIME$$

where

EGP = EGGPT/CPIT

EGPC = EGGQT/POPUS

MEATPC = (PORKQT+FBEFQT+NFBFQT+NFBIMT+CHIKQT+TURKQT)/POPUS

EGGPT = Price of eggs received by farmers, cents/dozen

EGGQT = Egg production, million dozen

3.2 Method of Estimation

Chapter 2 provided the main theoretical foundations for consumer behavior and how the classical demand theory relates to empirical analysis. It is noted, however, that there exists a gap between theory and applied empirical analysis.

Common sense and knowledge of the market of the commodity under consideration provide some basis for determining market demand not only as function of prices and income but of other relevant factors. The present analysis of livestock demand follows a pragmatic approach. That is, a specific utility function is not explicitly imposed and the demand specifications of the demand equations for livestock used in this study deviate from the theoretically derived demand functions. This approach is adopted in order to incorporate in the model specification some dynamic relationships and to account for observed changes in the demand structure of some animal products, particularly beef.

Ordinary least squares is employed in estimating the equations in the model. This estimation technique is considered adequate due to the recursive nature of the model specifications. The demand model was estimated using annual observations over the period 1955 through 1984. A long data series was used in order to investigate structural changes in demand for animal products. In the case of the supply model, different sample periods were used in estimating various structural equations. The various periods of time tried to cover at least one complete production cycle for the particular commodities considered. The time periods used for estimation and the lagged specification of supply equations are both relevant considerations in capturing the dynamics of livestock supply structural relationships.

3.3 Empirical Results of Updates and Reestimation of the Base Model

Following the design of the systems structure, is the specification and estimation of model equations. After estimation, each equation is verified and evaluated based on regression diagnostics. An essential part of verification involves the evaluation of the plausibility of parameter estimates. This section presents the results of initial specification, estimation and revision. The equations are reported with the estimates of the structural coefficients and statistics describing the accuracy of these estimates. Statistical measures such as coefficient of determination (simple and adjusted), Durbin-Watson statistic, F-value and turning point errors are also reported to provide a general evaluation of each regression equation. A plot of the residuals is also given following each equation. A graph of the fitted values and actual values are also reported.

3.3.1 Livestock and Poultry Demand

Least squares estimates of the base demand model for beef, pork, chicken, turkey, and eggs are presented in Equation 3.1 through Equation 3.5. With respect to goodness-of-fit measures, the coefficient of determination for each price equation indicated high degrees of explanatory power. Each inverse demand equation has a negative own-quantity coefficient and exhibited correct signs for the substitute commodities included. The t-values associated with the coefficients suggested, in most cases, the coefficients were significantly different from zero at the .05 level. Estimated income effects on livestock and poultry prices were positive and significant. The estimated mean price and income flexibilities calculated from the price equations are presented in Table 3.1. Ideally, one could draw comparisons of the estimated flexibilities with the results of other studies. However, results from other studies on meat demand are not directly comparable due to differences in model specification (i.e., use of quantity dependent form demand model), functional forms, and data transformations used. More recent estimates of direct and income flexibilities provide limited areas for comparisons.

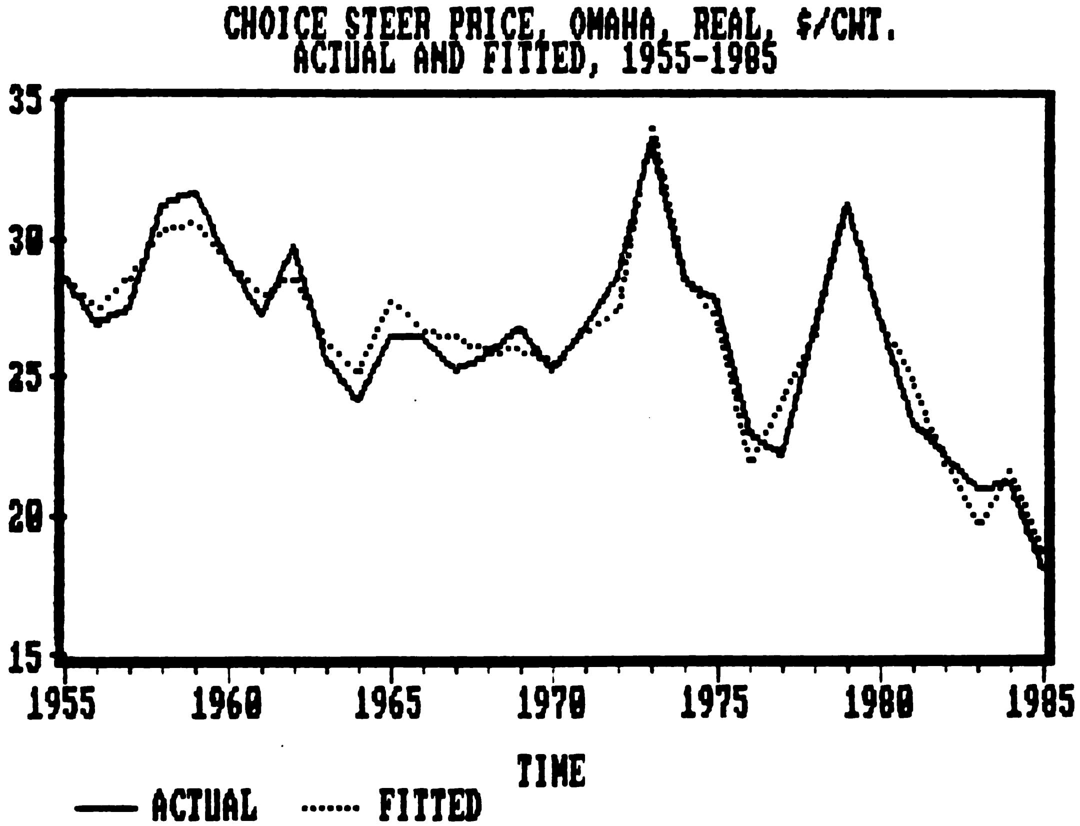
The estimates of own-quantity flexibilities are all negative as implied by economic theory (Table 3.1). The magnitudes of the estimated flexibilites indicate flexible

Equation 3.1

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	41.439147	3.1913917	12.984663	0.000
BFPC	-0.5053932	0.0457767	-11.040413	0.000
PKPC	-0.0603790	0.0605213	-0.9976495	0.329
DINC	0.0157998	0.0020005	7.8980762	0.000
DVT73	-1.1510583	0.1967053	-5.8516891	0.000
DV730N	84.641332	14.793863	5.7213815	0.000
DVT80	-1.3234203	0.3361368	-3.9371481	0.001
DV800N	103.98569	27.100764	3.8370021	0.001

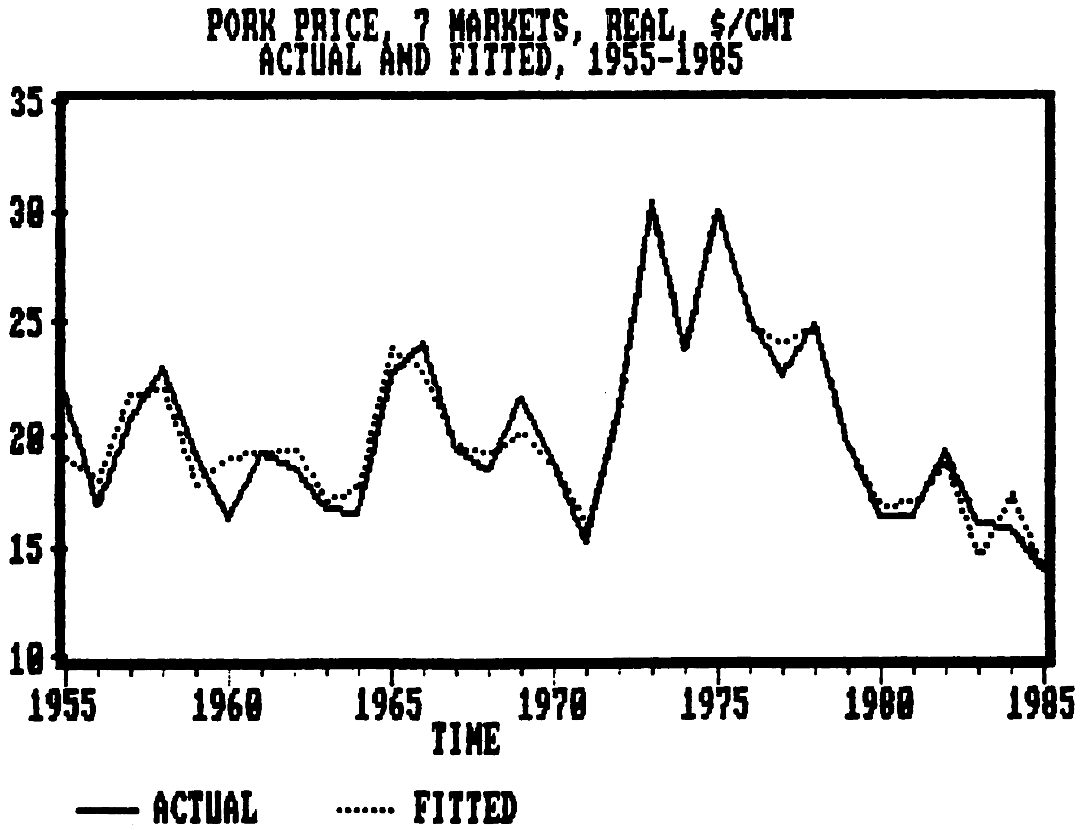
R-squared	0.936548	Mean of dependent var	26.41577
Adjusted R-squared	0.917237	S.D. of dependent var	3.424503
S.E. of regression	0.985179	Sum of squared resid	22.32330
Durbin-Watson stat	2.173877	F-statistic	48.49737
Log likelihood	-38.89757		



Equation 3.2
SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	47.746683	4.3604397	10.949970	0.000
PKPC	-0.6797290	0.0807323	-8.4195392	0.000
BFPC	-0.2154741	0.0611695	-3.5225764	0.002
POULPC	-0.1739415	0.1225566	-1.4192753	0.170
DINC	0.0168523	0.0036854	4.5726642	0.000
DV73ON	94.351923	20.888885	4.5168483	0.000
DVT73	-1.2696901	0.2760163	-4.6000544	0.000
DV80ON	74.890653	37.055914	2.0210175	0.056
DVT80	-0.8930845	0.4578674	-1.9505307	0.064

R-squared	0.923445	Mean of dependent var	20.12544
Adjusted R-squared	0.895607	S.D. of dependent var	4.067107
S.E. of regression	1.314080	Sum of squared resid	37.98971
Durbin-Watson stat	2.270103	F-statistic	33.17188
Log likelihood	-47.13868		

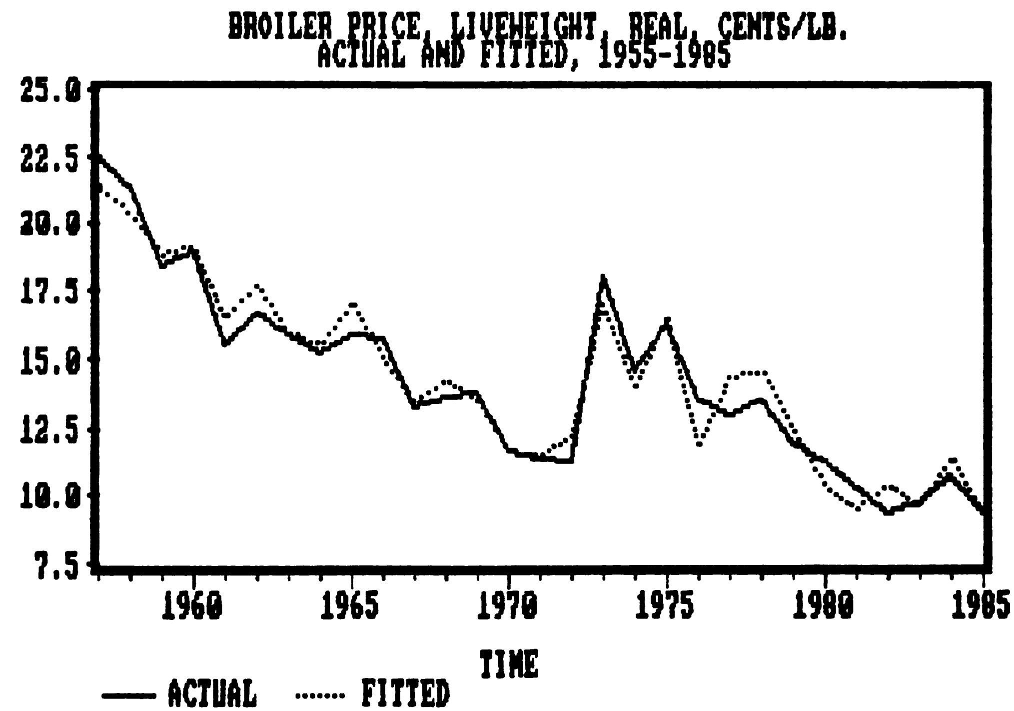


Equation 3.3

SMPL 1957 - 1985
29 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	44.191499	2.6930120	16.409693	0.000
POULPC	-0.5874031	0.0679211	-8.6483121	0.000
BFPC	-0.2107667	0.0287073	-7.3419269	0.000
PKPC	-0.1911915	0.0411179	-4.6498321	0.000
DINC	0.0114686	0.0018121	6.3289847	0.000

R-squared	0.944611	Mean of dependent var	14.24397
Adjusted R-squared	0.935380	S.D. of dependent var	3.444028
S.E. of regression	0.875491	Sum of squared resid	18.39563
Durbin-Watson stat	2.107199	F-statistic	102.3248
Log likelihood	-34.54907		

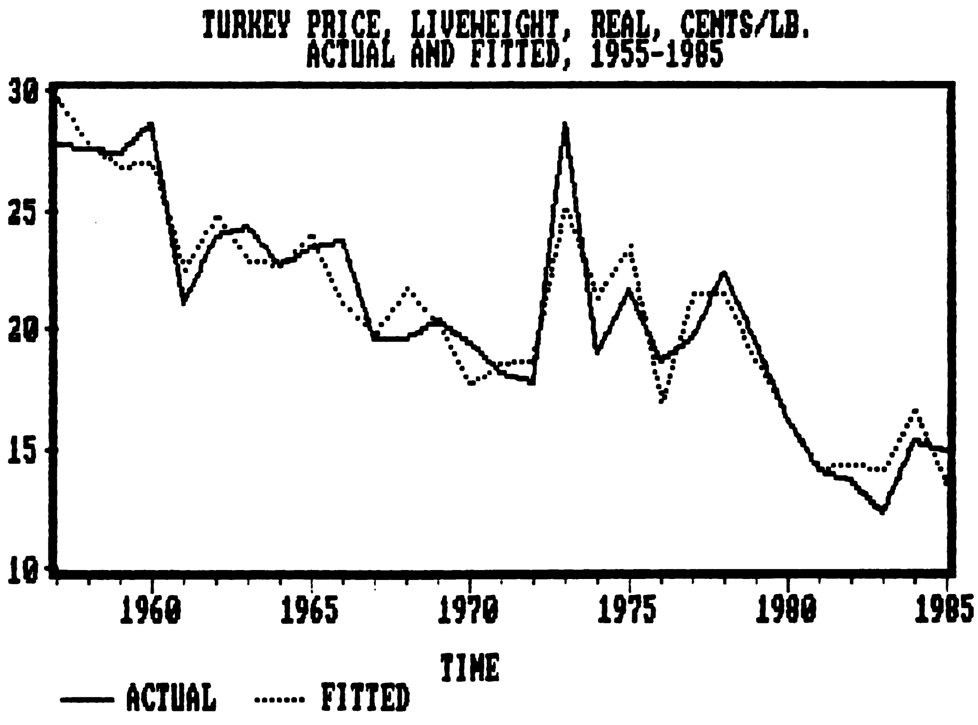


Equation 3.4

SMPL 1957 - 1985
29 Observations
LS // Dependent Variable is TKP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	50.469746	5.0525494	9.9889664	0.000
POULPC	-0.9589127	0.1274316	-7.5249202	0.000
BFPC	-0.2766433	0.0538597	-5.1363654	0.000
PKPC	-0.1206139	0.0771443	-1.5634848	0.131
DINC	0.0187542	0.0033998	5.5162919	0.000

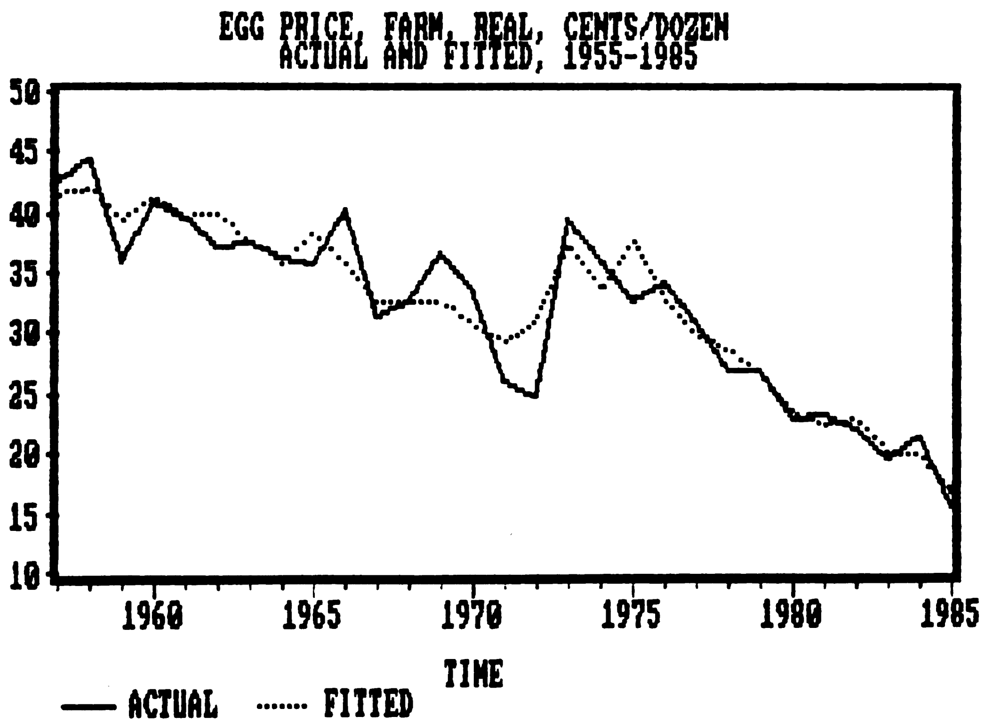
R-squared	0.890910	Mean of dependent var	20.72692
Adjusted R-squared	0.872728	S.D. of dependent var	4.604238
S.E. of regression	1.642571	Sum of squared resid	64.75291
Durbin-Watson stat	2.424243	F-statistic	49.00035
Log likelihood	-52.79682		



Equation 3.5
SMPL 1957 - 1985
29 Observations
LS // Dependent Variable is EGP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	106.32114	23.117999	4.5990634	0.000
EGPC	-0.7279443	0.5868599	-1.2404057	0.227
MEATPC	-0.3205785	0.0807950	-3.9678010	0.001
DINC	0.0062668	0.0049988	1.2536619	0.223
DVT77	-1.5168354	0.3720337	-4.0771453	0.000
DV770N	112.22943	29.926386	3.7501832	0.001

R-squared	0.887944	Mean of dependent var	31.91413
Adjusted R-squared	0.863584	S.D. of dependent var	7.647364
S.E. of regression	2.824523	Sum of squared resid	183.4924
Durbin-Watson stat	2.358896	F-statistic	36.45077
Log likelihood	-67.89994		



prices for beef, pork, chicken, turkey, and eggs. This implies that a one percent change in the quantity available for consumption of these commodities will result to more than proportionate change in their price. Interestingly, turkey has the highest own-quantity flexibility relative to the own quantity flexibilities of the other three commodities (in absolute value).

Estimated cattle price equation with poultry per capita supply as one explanatory variable showed the latter to be insignificant and has a wrong sign. Equation 3.1 excludes poultry quantity. Other studies, however, indicated that poultry, particulary chickens, has become a strong substitute for beef starting in the late 1970s (Chavas, 1983; Cornell, 1983). The trend variables (DVT73 and DVT80) indicate a decline in real fed beef prices by about $1.16 per year starting in 1973 and by about $1.13 per year starting in 1980. Perhaps, this is a result of the declining demand for beef starting about mid 1970s.

The estimated income flexibility of beef is significantly positive and is greater than unity. This implies that beef demand is responsive to changes in per capita disposable income. Beef has the largest cross-quantity effect on pork, broiler and turkey prices as indicated by a higher cross- quantity flexibility on beef relative to pork in the poultry price equations, and relative to poultry in the hog price equation.

The significantly negative estimate of cross quantity flexibility of poultry with respect to beef indicate the latter to be a significant substitute for chicken and turkey. The demand relationship for turkeys is represented in the turkey price equation (Equation 3.4). The level of turkey price is associated with the level of poultry, pork and beef production per capita. All coefficients are significant at the .05 level except the pork quantity coefficient. A strong income effect on turkey prices is also indicated by the income flexibility estimate.

The demand model for eggs (Equation 3.5) identifies the relationship between egg price and egg production per capita, livestock and poultry production per capita (sum of beef, pork and poultry), income and population. Changes in tastes and preferences, as well as the growing dietary concern is proxied by the time variable. The equation indicates a substitution relationship between meat and eggs. The coefficients are significant at the .05 level.

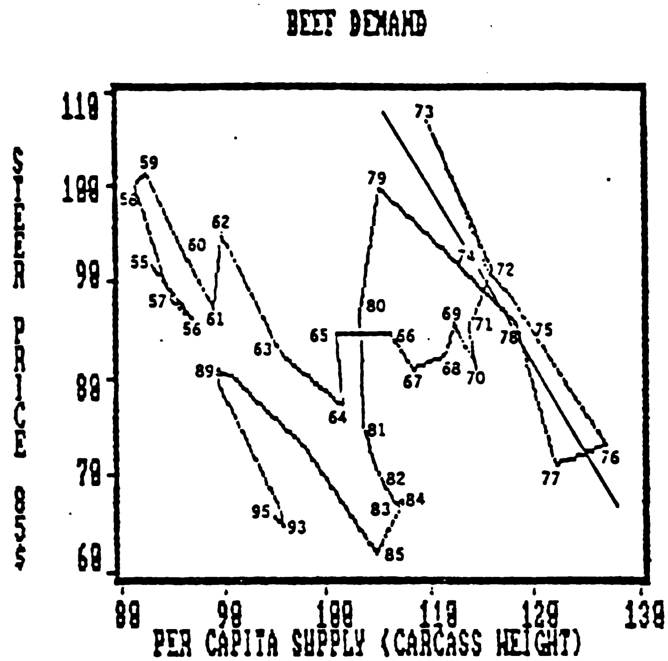
Figure 3.3, a scatter plot relating per capita supply to deflated steer prices, shows how the demand for beef has shifted with time. It has been hypothesized by some that the figure implies steadily increasing demand for beef from the 1950's through the 1970's and then appears to shift backwards in the 1980's. Some explanations include decreasing positive income effects on beef demand, competition from poultry, and health and diet concerns.

Table 3.1 Estimates of Quantity and Income Flexibility of Aggregate Demand for Meat

Deflated Price Of Meat	Domestic Supply (= Consumption) Per Person					Real Disposable Income Per Capita
	Beef	Pork	Poultry	Eggs	Total Meat	
Beef	-2.02	-0.16				1.73
Pork	-1.12	-2.11	-0.43			2.25
Broiler	-1.58	-0.83	-2.00			2.34
Turkey	-1.40	-0.34	-2.29			2.63
Eggs				-1.11	-1.43	2.10

Total Meat includes beef, pork and poultry. Flexibilities are calculated at the means.

Figure 3.3


BEEF DEMAND
STEER PRICE 85$
110
100
90
80
70
60
80
90
100
110
120
130
PER CAPITA SUPPLY (CARCASS WEIGHT)
59
58
55
57
56
60
61
62
63
65
64
89
95
93
79
80
81
82
83
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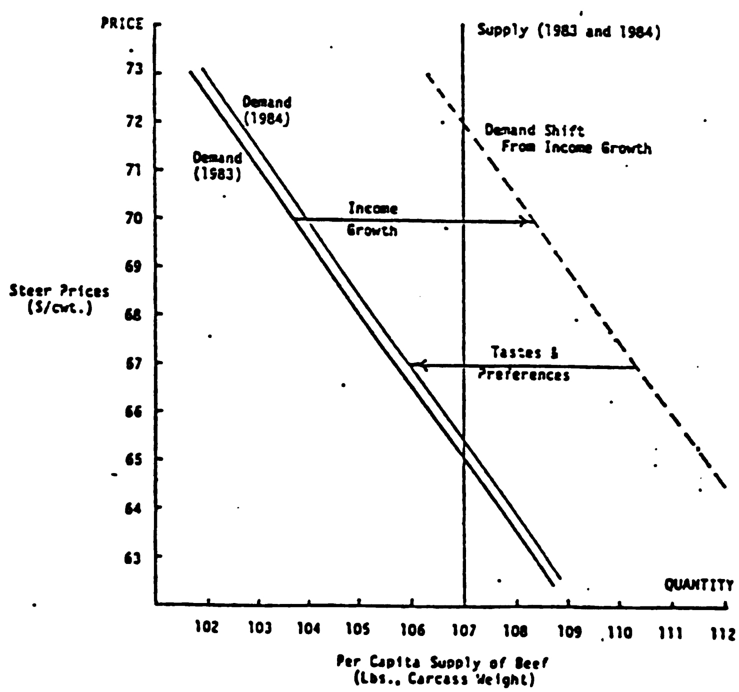

Change in Beef Demand From 1983 to 1984
PRICE
Steer Prices
($/cwt.)
73
72
71
70
69
68
67
66
65
64
63
Supply (1983 and 1984)
Demand
(1984)
Demand
(1983)
Demand Shift
From Income Growth
Income
Growth
Tastes &
Preferences
QUANTITY
102
103
104
105
106
107
108
109
110
111
112
Per Capita Supply of Beef
(Lbs., Carcass Weight)

The positive shifts to the right of beef demand appears to have ended around 1972. While beef demand did not appear to be decreasing, it did not increase despite the increase in personal disposable income during the period 1972 to 1979. While this could possibly be explained by a decreasing impact of income effects on beef demand, as other studies (Chavas, 1983) have argued, that would contradict cross-sectional studies indicating continued positive effects of income on beef demand. It is also hard to believe a negative income effect, which would be needed to explain the backward shifts in demand seen in the 1980's. While some decrease in income elasticity is likely, upon inspection, the hypothesis of new factors affecting the demand for beef appears more plausible.

The hypothesis in this paper is that there is still a positive response of beef demand to income, but it was being offset by other factors during the mid to late 1970's and overshadowed by other factors in the 1980's. Figure 3.4 gives a visual example of this hypothesis. Income growth from 1983 to 1984, given the same per capita availability, would have shifted the demand curve to the right enough to increase nominal steer prices about $7/cwt, but other factors, which are labeled tastes and preferences, shifted the demand curve back to the left by about the same amount. Real steer prices remained the same as can be seen at the intersection of the supply and demand curves, at around

$65/cwt.

In order to test the hypothesis, several equations were fitted over historical time periods using ordinary least squares. Using Figure 3.3 as a guide, a fairly standard price dependent beef demand equation was fitted over three time periods. Beef inverse demand equation was fitted over the time period 1955-1972, a period of continually growing demand (Equation 3.1.1). As can be seen, the equation with real steer prices as the dependent variable and per capita beef quantity, per capita pork quantity , and per capita real disposable income as the explanatory variables (poultry quantity was insignificant and had the wrong sign and therefore was not used), has good statistical properties. In particular, the expalanatory variables in Equation 3.1.1 accounted for 91 percent of the variations in real steer prices.

Equation 3.1.2, using a 1955-1979 time period, showed much less explanatory power, 67 percent, even though the same explanatory variables were used, and pork quantity was insignificant. The same specification was estimated for the period 1955 through 1984 (Equation 3.1.3). Only 18 percent of the variation in steer prices was explained and none of the variables were significant at the .05 level. The results shown in Equation 3.1.1 through 3.1.3 indicate a possible change in the structure of beef demand in the 1970s. Clearly, equation 3.1.3 is missing the effects of other

Equation 3.1.1

SMPL 1955 - 1972
18 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	40.508894	2.6028387	15.563352	0.000
BFPC	-0.7457245	0.0716480	-10.408167	0.000
PKPC	-0.0052252	0.0538104	-0.0971034	0.924
DINC	0.0242890	0.0027044	8.9813487	0.000

R-squared	0.912754	Mean of dependent var	27.40602
Adjusted R-squared	0.894058	S.D. of dependent var	2.071100
S.E. of regression	0.674116	Sum of squared resid	6.362053
Durbin-Watson stat	2.546642	F-statistic	48.82182
Log likelihood	-16.18071		

Equation 3.1.2

SMPL 1955 - 1979
25 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	39.546875	5.1247696	7.7168102	0.000
BFPC	-0.3919132	0.0611227	-6.4119098	0.000
PKPC	0.0205899	0.0789264	0.2608745	0.797
DINC	0.0100282	0.0018984	5.2825223	0.000

R-squared	0.675075	Mean of dependent var	27.43773
Adjusted R-squared	0.628657	S.D. of dependent var	2.674293
S.E. of regression	1.629659	Sum of squared resid	55.77154
Durbin-Watson stat	0.968659	F-statistic	14.54342
Log likelihood	-45.50331		

Equation 3.1.3

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	36.208649	9.3698522	3.8643778	0.001
BFPC	-0.0057054	0.0783032	-0.0728633	0.942
PKPC	-0.0030973	0.1386548	-0.0223380	0.982
DINC	-0.0031787	0.0021411	-1.4846017	0.149

R-squared	0.236078	Mean of dependent var	26.41577
Adjusted R-squared	0.151198	S.D. of dependent var	3.424503
S.E. of regression	3.155010	Sum of squared resid	268.7604
Durbin-Watson stat	0.865791	F-statistic	2.781312
Log likelihood	-77.46450		

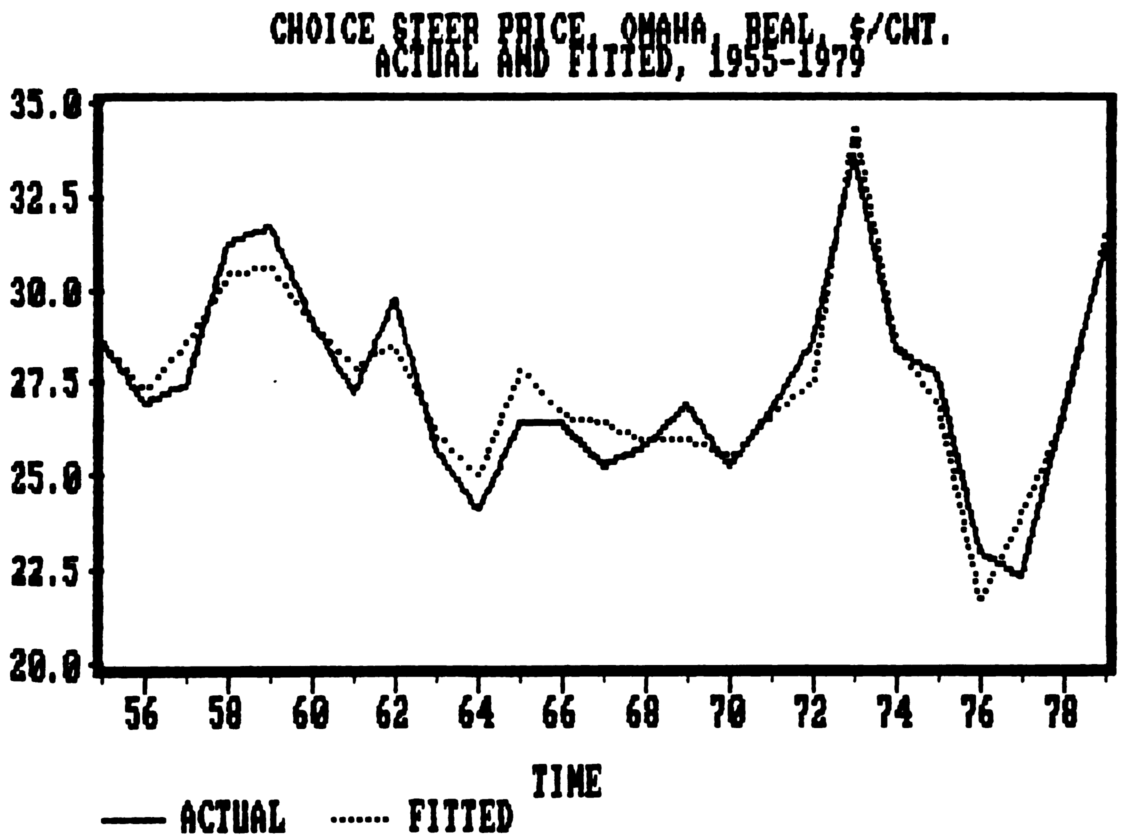
important variables which contributed to the change in the beef demand structure starting in the mid 1970s.

An alternative formulation would be to include a proxy for the missing factors. As mentioned, the missing variables are likely to be such factors as changes in tastes and preferences due to the increasing health and diet concerns of consumers. A proxy for the missing variables would be difficult to find. However, it is reasonable to expect that changes in preferences occur over a long period of time and will be in the same direction each year. Given this assumption, a time trend was chosen as the proxy. Equation 3.1.4 allows the time trend to enter as a variable starting in 1973, the period hypothesized to be the beginning of the structural change. When to begin to allow the effects of the proxy trend variable was determined by the conclusions reached observing Figure 3.0. Equation 3.1 also includes variables from 1980 on in order to account for the increased effect of the missing variables on beef demand starting in 1980. As shown, this formulation explains 93 percent of the variation in steer prices over the period and the income coefficient is not only significant but also quite large. The income flexibility estimated at the means in equation 3.1.1 (estimated from 1955 to 1972) was 2.2 and the income flexibility in Equation 3.1.4 (estimated from 1955 to 1979) is 1.88. While the income effect on beef prices has seemed to drop somewhat between the two period, Equation 3.1.4

SMPL 1955 - 1979
25 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	41.738133	3.2452105	12.861456	0.000
BFPC	-0.5275286	0.0467754	-11.277905	0.000
PKPC	-0.0694354	0.0623443	-1.1137411	0.279
DINC	0.0167784	0.0020552	8.1640014	0.000
DV730N	86.739155	14.516953	5.9750248	0.000
DVT73	-1.1834104	0.1932309	-6.1243337	0.000

R-squared	0.897543	Mean of dependent var	27.43773
Adjusted R-squared	0.870580	S.D. of dependent var	2.674293
S.E. of regression	0.962077	Sum of squared resid	17.58623
Durbin-Watson stat	2.167364	F-statistic	33.28855
Log likelihood	-31.07647		



it is still a very significant factor in the determination of beef demand. The trend variables in Equation 1.1.4 have the expected negative signs and are significant at the .05 level.

The magnitude of the structural change in the beef sector is shown by the coefficients of the trend variables. Given all the other variables were held constant, nominal steer prices would drop over $7/cwt. per year due to the shift away from beef approximated by the proxy trend variables. The results imply that beef demand is still responsive to income changes.

3.3.2 Livestock and Poultry Production

The empirical results of the supply models as shown in the individual supply equations appear reasonable. Year-to-year changes in the beef cow numbers are explained very well by the lagged beef cow inventory and lagged feeder calf prices (Equation 3.6).

The pork supply model (Equation 3.9) showed expected and significant results for all variables. Variation in pork slaughter is explained by the variation in sows farrowing and the hog-corn price ratio. The ratio between hog and corn prices is a proxy variable to capture the incentive to feed to lighter or heavier slaughter weights.

As indicated earlier, the annual specification for the poultry supply model is not appropriate because supply adjustments occur within the year. Hence, the empirical results presented for broilers, turkeys and eggs (Equations 3.10, 3.11, and 3.12, respectively) should be interpreted considering the limitations imposed by the time aggregation problems.

In the case of turkeys (Equation 3.11) , the results were encouraging as the signs of all coefficients are as expected and significant at the 5 percent level. The estimated equation for broiler supply is shown in Equation 3.10. The explanatory variables explain year-to-year variation in broiler supply very well. The labor efficiencycoefficient, as well as the product and input price coefficients, have expected signs and are significant at the 5 percent level.

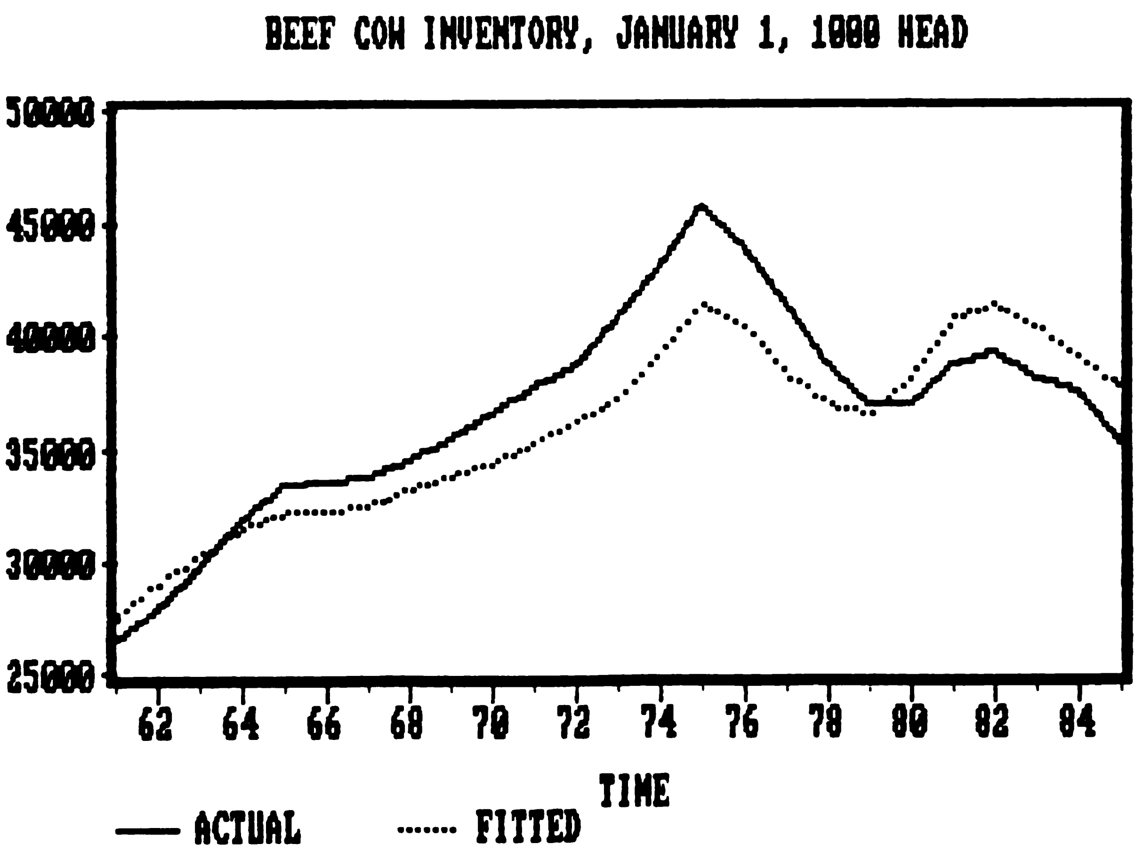
The egg supply equation is given in Equation 3.12. The coefficients on corn and egg prices, as well as on labor efficiency are all significant at the .05 level. The empirical results for eggs reflects the weaknesses of an annual specification. However, 74 percent of the year-to-year variation in egg supply is explained by the included explanatory variables.

Equation 3.6

SMPL 1961 - 1985
25 Observations
LS // Dependent Variable is BFCOWT
Convergence achieved after 2 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	45.712125	5108.6108	0.0089481	0.993
BFCOWT(-1)	0.8407799	0.1318957	6.3745827	0.000
BCP(-1)	48.291018	31.166338	1.5494607	0.138
BCP(-2)	135.57599	29.189119	4.6447442	0.000
BCP(-3)	25.037726	32.829018	0.7626706	0.455
AR(1)	0.6371231	0.2371539	2.6865385	0.015

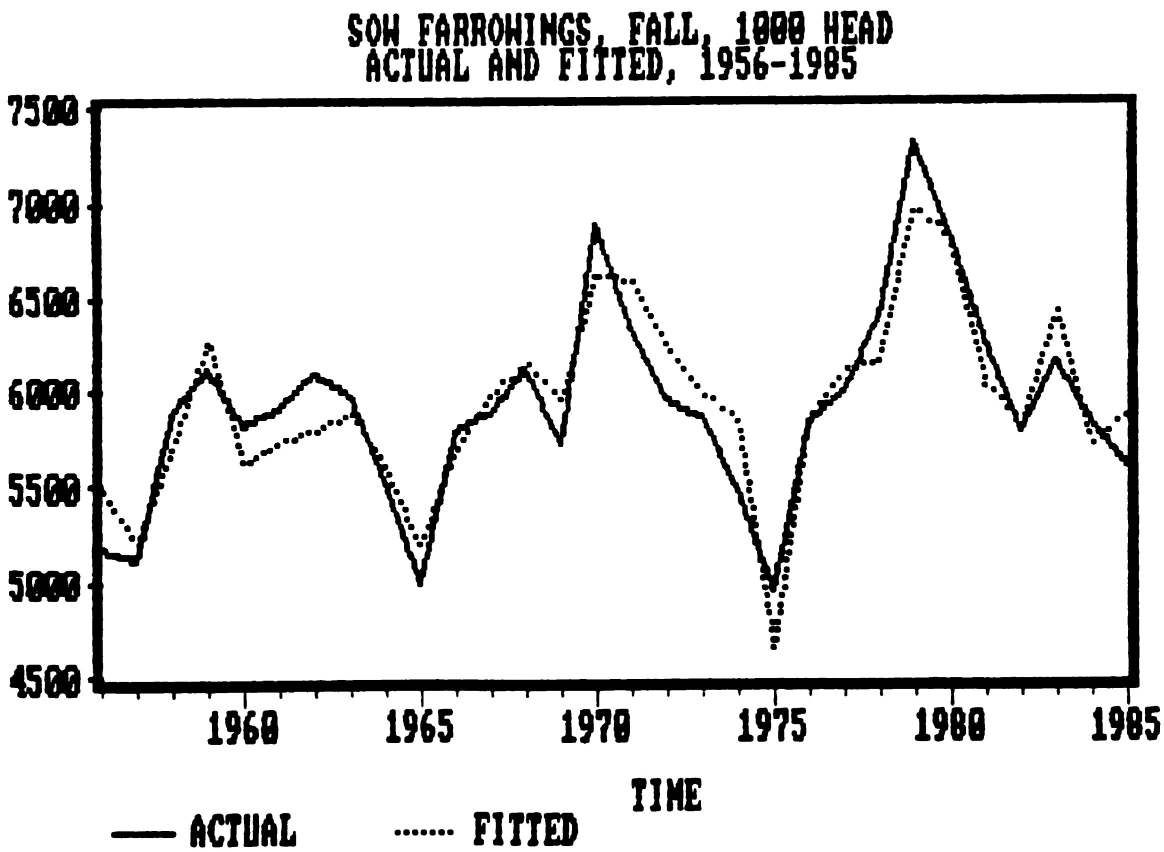
R-squared	0.979318	Mean of dependent var	36700.00
Adjusted R-squared	0.973875	S.D. of dependent var	4688.274
S.E. of regression	757.7713	Sum of squared resid	10910131
Durbin-Watson stat	2.107883	F-statistic	179.9345
Log likelihood	-197.8025		



Equation 3.7
SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is SOWFFT

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	2375.4938	606.03742	3.9197148	0.001
SOWFST	0.0228918	0.0766093	0.2988116	0.768
PPORK(-1)	41.643534	15.506745	2.6855110	0.013
CORNP(-1)	-921.37351	226.14519	-4.0742564	0.000
SOYMP(-1)	-32.136261	40.969699	-0.7843910	0.440
SOWFS7	0.0085632	0.0015192	5.6368237	0.000

R-squared	0.842866	Mean of dependent var	5928.567
Adjusted R-squared	0.810130	S.D. of dependent var	520.9526
S.E. of regression	227.0003	Sum of squared resid	1236700.
Durbin-Watson stat	1.919445	F-statistic	25.74720
Log likelihood	-201.9695		



Equation 3.8

SMPL 1962 - 1985
24 Observations
LS // Dependent Variable is SOWFST

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	-1733.2951	1005.3230	-1.7241176	0.103
SOWFST(-1)	1.1474680	0.1232975	9.3064985	0.000
PPORK(-1)	231.78006	25.402625	9.1242563	0.000
CORNP(-1)	-1181.6455	331.27364	-3.5669771	0.002
CORNP(-2)	-817.33980	271.53710	-3.0100484	0.008
SOYMP(-1)	-103.91999	45.556603	-2.2811182	0.036
SOYMP(-2)	-271.16355	62.688098	-4.3255986	0.000

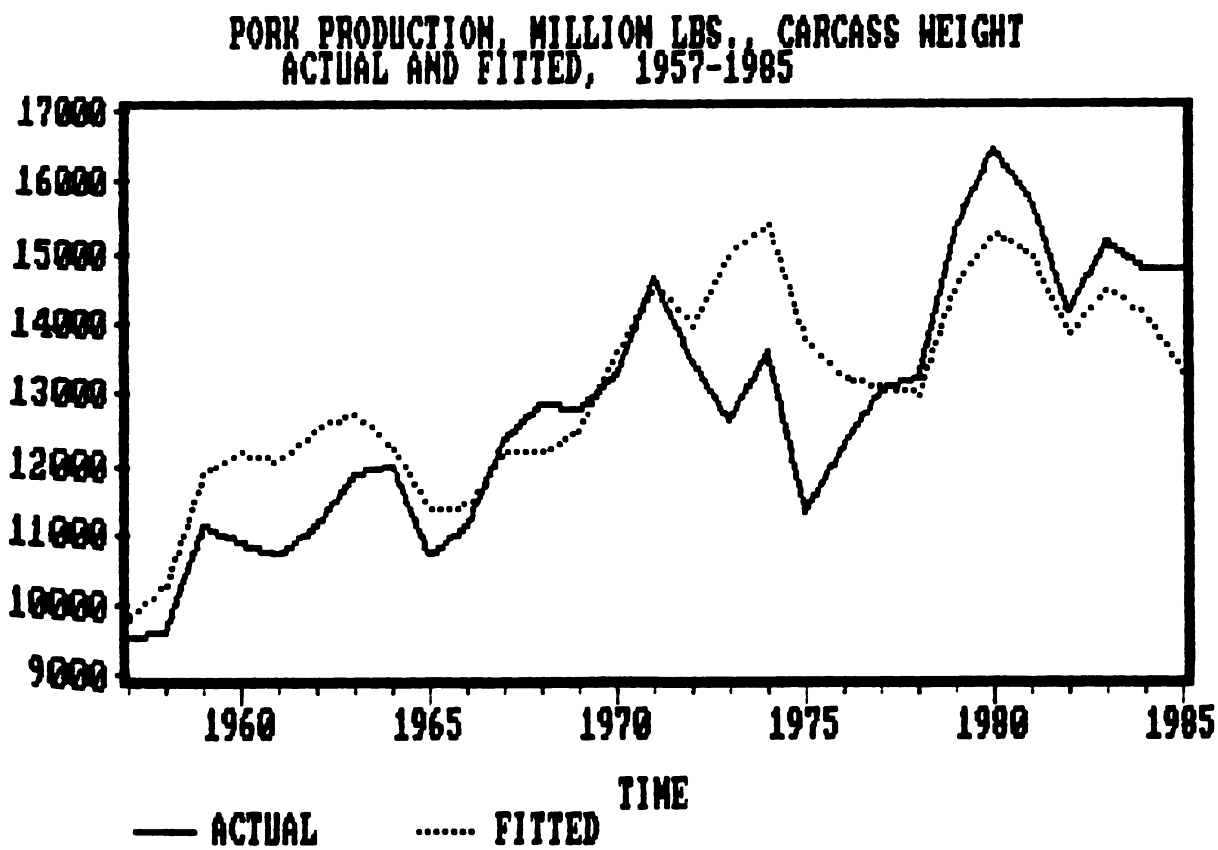
R-squared	0.890004	Mean of dependent var	6364.667
Adjusted R-squared	0.851182	S.D. of dependent var	601.1179
S.E. of regression	231.8932	Sum of squared resid	914165.7
Durbin-Watson stat	2.150521	F-statistic	22.92513
Log likelihood	-160.6271		

Equation 3.9

SMPL 1957 - 1985
29 Observations
LS // Dependent Variable is PORKQT

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	-6259.2876	2310.0833	-2.7095506	0.012
PORKQT(-1)	0.8430322	0.0865438	9.7411003	0.000
PKCRR	130.77796	36.648778	3.5684125	0.002
PKSMPR	192.59238	157.00118	1.2266938	0.232
SOWS	0.4087656	0.1409153	2.9007887	0.008

R-squared	0.878869	Mean of dependent var	12764.83
Adjusted R-squared	0.858680	S.D. of dependent var	1816.732
S.E. of regression	682.9554	Sum of squared resid	11194273
Durbin-Watson stat	1.715381	F-statistic	43.53305
Log likelihood	-227.6717		

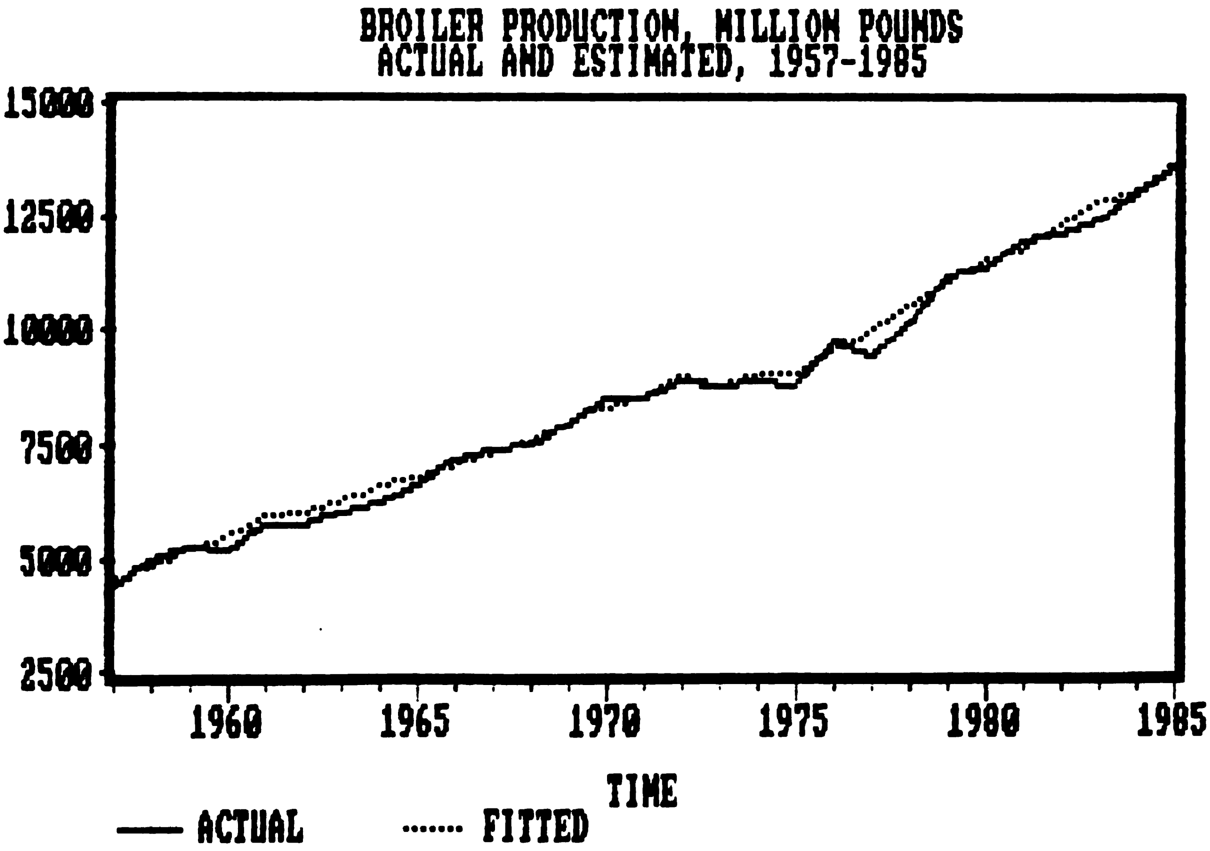


Equation 3.10

SMPL 1957 - 1985
29 Observations
LS // Dependent Variable is CHIKQT
Convergence achieved after 2 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	727.52703	791.13939	0.9195940	0.368
CHIKQT(-1)	1.0293688	0.0382775	26.892248	0.000
CHP(-1)	81.243162	35.072826	2.3164133	0.030
CORNP(-1)	-576.35295	289.06309	-1.9938656	0.059
SOYMP(-1)	-86.521781	54.612015	-1.5842994	0.127
LHFW	-1186.7042	624.46583	-1.9003509	0.071
AR(1)	-0.4106313	0.1974805	-2.0793507	0.049

R-squared	0.990399	Mean of dependent var	8534.076
Adjusted R-squared	0.987781	S.D. of dependent var	2630.577
S.E. of regression	290.7855	Sum of squared resid	1860237.
Durbin-Watson stat	2.416411	F-statistic	378.2452
Log likelihood	-201.6485		

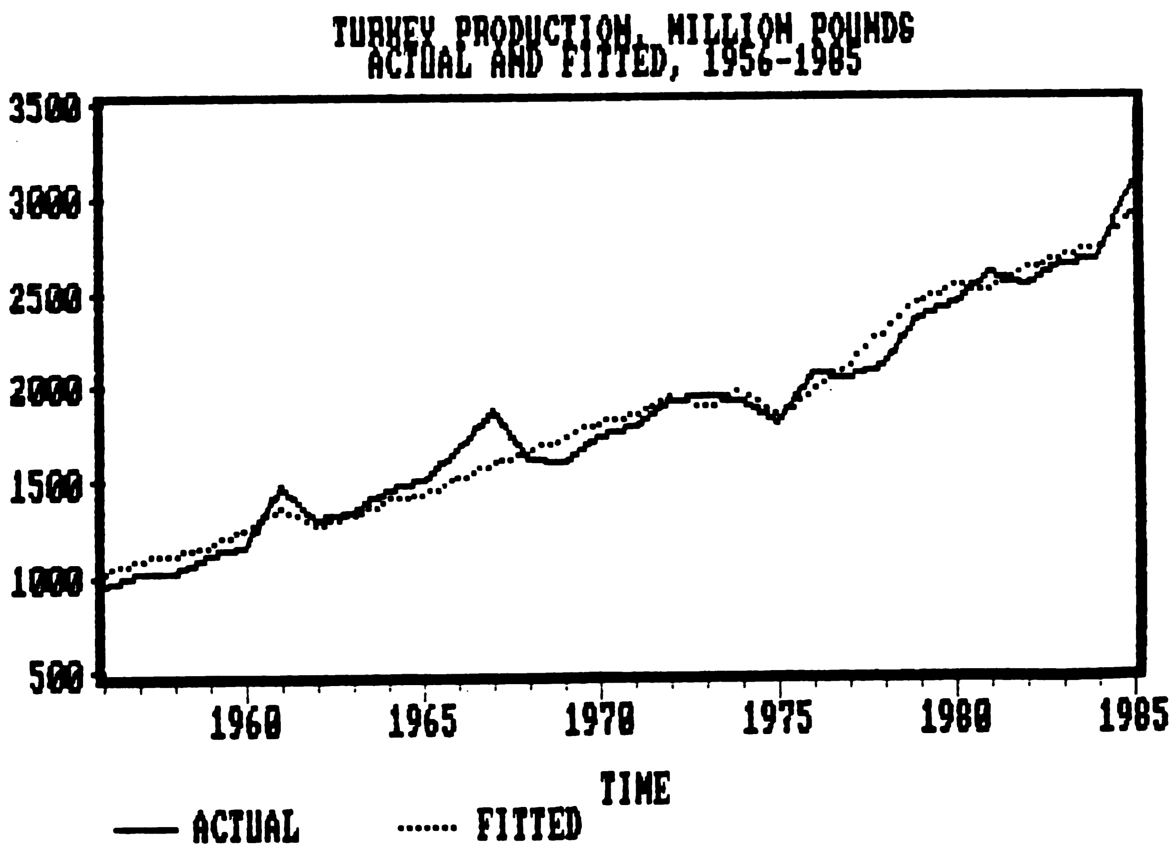


Equation 3.11

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is TURKQT

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	135.91260	370.40986	0.3669249	0.717
TURKQT(-1)	0.4056615	0.2175873	1.8643623	0.075
TKP(-1)	19.936798	8.6811095	2.2965725	0.031
CORNP(-1)	-274.45986	96.847926	-2.8339260	0.009
SOYMP(-1)	-3.4079655	21.155888	-0.1610883	0.873
LHFW	189.22256	257.39082	0.7351566	0.470
T	49.349289	14.122704	3.4943230	0.002

R-squared	0.969940	Mean of dependent var	1819.923
Adjusted R-squared	0.962098	S.D. of dependent var	542.9502
S.E. of regression	105.7038	Sum of squared resid	256986.0
Durbin-Watson stat	1.906468	F-statistic	123.6887
Log likelihood	-178.4018		

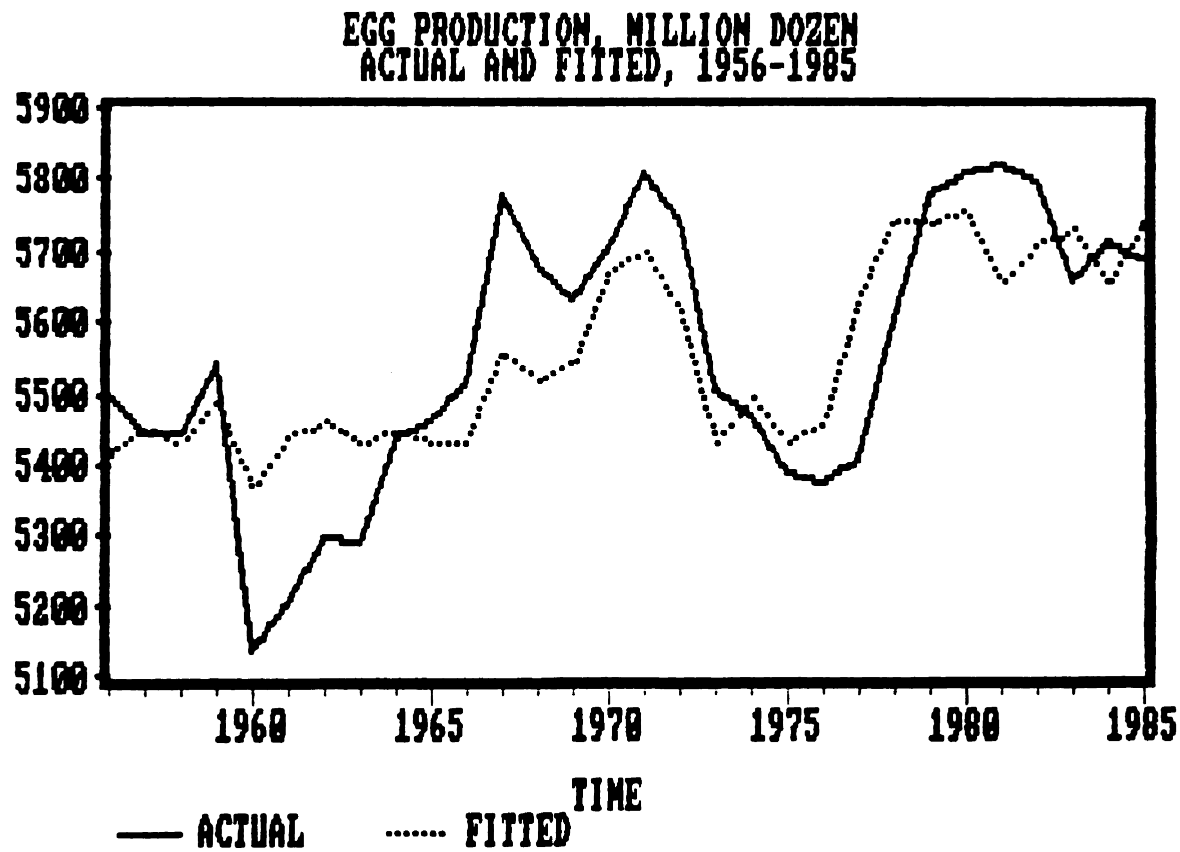


Equation 3.12

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is EGGQT

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	382.28046	919.13399	0.4159137	0.681
EGGQT(-1)	0.7886876	0.1445895	5.4546660	0.000
EGP(-1)	25.896192	7.7450515	3.3435791	0.003
CORNP(-1)	-299.04249	102.71216	-2.9114614	0.008
LHFW	-20.295221	189.37808	-0.1071677	0.916
T	20.299362	7.1752378	2.8290855	0.009

R-squared	0.752046	Mean of dependent var	5553.510
Adjusted R-squared	0.700389	S.D. of dependent var	192.1106
S.E. of regression	105.1550	Sum of squared resid	265381.9
Durbin-Watson stat	1.949571	F-statistic	14.55845
Log likelihood	-178.8841		



3.4 Summary and Conclusions

A recursive annual model of U.S. livestock and poultry is specified and estimated to generate intermediate and long-run projections of inventory, production, and prices for beef, pork, broiler, turkey, and eggs. Separate estimates are made for each category. The beef sector models are represented by producer decision variables and biological response variables. Producer decision variables include the number of animals, the weight at which an animal is slaughtered and the rate of herd expansion or contraction. Biological response variables are determined primarily by such factors as death rates and calving rates. The beef sector models estimates beef cow inventory, steer and heifer slaughter, and cow and bull slaughter. The supply structure for pork is determined largely by the relationship between hog and feed prices. Separate equations are used to represent fall and spring farrowings.

An inverse demand model is used to represent the null hypothesis of constant parameters in the demand for beef, pork, broiler, and turkey. Preliminary estimations and analysis of scatter plots of per capita beef production and real steer prices suggest a shift in beef demand during mid-1970s and early 1980s. Estimated price equations using the 1955-1984 period without accounting for these shifts have poor fits and indicate misspecification. The beef and pork price equations fail to include the effects of variables which contributed to the change in red meat demand.

The missing variables are hypothesized to be factors affecting the consumers preference function. It is reasonable to expect that changes in preferences occur over a long period of time and will be in the same direction each year. Given this assumption, time trend shifter variables were chosen as proxy for the missing variables. Based on the scatter plot analysis, trend shifter variables were allowed to enter starting in 1973 and again starting in 1980. The magnitude of the shift in demand is indicated by the coefficients of the trend variables. Nominal steer prices drop over $7/cwt. per year due to the shift away from beef approximated by the proxy trend variables, ceteris paribus. The results imply that beef demand is still responsive to income changes.

The results of preliminary analysis of structural change in beef demand carried out in this chapter provide useful insight in further analysis and identification of an appropriate beef demand model. The possibility of parameter variation due to structural change implies that inference based on constant parameter model maybe misleading. Further analysis to identify the timing and pattern of change are essential in identifying more appropriate specifications of parameter variation. The methods to carry out such analysis are discussed in the following chapter.

CHAPTER 4

ANALYSIS OF PARAMETER STABILITY AND STRUCTURAL CHANGE IN THE U.S. MARKET DEMAND FOR MEAT

4.1 Definition of Structural Change in Demand Analysis

Structural change in demand may be defined as any change in the parameters of the consumer's utility function. Since the utility function itself is not observable, changes in it function are not directly observable. Within the context of the classical demand theory, changes in the parameters or form of the utility function are reflected in the structure of the corresponding demand function. That is, assuming utility maximization by the consumer, any change in the utility function is manifested in the form and parameters of the derived demand relationship.

For empirical testing and estimation of structural change, the hypothesis of a change in the utility function is tested by considering changes (systematic and/or random) in the coefficients of the demand equation.[1] Moschini and Mielke (1984) defined parameter change to include a) change in functional form, b) change in the quantitative relationship between the regressors and dependent variable and c) change in the form of the stochastic process associated

[1] Chavas (986) considers this approach as a narrower definition of structural change. He notes that a shift in demand parameters may not necessarily imply structural change and that results may depend on the functional form used.

with the demand function.

4.2 Testing Structural Change

This section provides a brief review of methods that may be used to test whether there has been a structural change in demand relationships. Tests of structural shifts are important in the context of estimating models of economic relationships for policy analysis and forecasting. For most estimation of econometric models used in determining the effects of a policy change, a necessary condition is that of invariant economic structure (i.e., constancy of parameters relating dependent and independent variables, constant functional form and error parameters) with respect to the policy changes of interest. This necessary condition is assumed. When there is structural change this assumption is not justified. Lucas (1976) has shown that changes in policies are likely to induce changes in parameters of structural relationships. Testing possible changes in structural parameters is particularly useful in simulating the likely effects of policy changes.

4.3 Problems in Testing Structural Change

Conceptual problems exist in investigating whether structural change has occurred in demand by testing whether demand parameters have varied over time. The problem lies in the fact that parameter variation may arise because of structural change or due to misspecifications in constructing the demand models.[2]

Rausser, Mundlak, and Johnson (1981) identified types of model misspecifications that result in instability in model parameters. They argued that approximating highly nonlinear "true" relationships by a simple linear functional form may contribute strongly to the variation of the parameters. Also, they considered the use of aggregate data to contribute to parameter instability. Since the weights used to calculate aggregate data from different smaller units are likely to shift over time (as the relative importance of the individual units to the aggregate measure vary over time), the coefficients corresponding to the aggregate variable in the model vary over time. A third form of misspecification mentioned by Rausser, et.al., (1981) involves the use of proxy variables due to scarcity and absence of data of the "true" variables. They pointed out that the "relationship between the true variable and its proxy can be expected to change over time . . . changes in the true variables which measure the actual economic stimuli induce instability in the estimated parameters for the

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[2] For details about the relationship between specification errors and parameter instability, see Dufour (1982) and Harvey (Chapter 2, section 7), 1981.

proxy variables."[3]

Another cause of parameter instability is the omission of important explanatory variables. The omitted variables are usually the unobservable variables such as preference changes and formation of new consumption habits, changes in institutions and technology and other similar factors.

The three-stage approach employed in this study attempts to minimize the above problems by conducting tests to determine departures from the fitted functional form prior to specification of varying parameters.

4.4 Exploratory Approach of Testing Structural Change

In the absence of information regarding specific type and timing of structural change, the analyst may have to explore and carefully analyze the available data and detect instability patterns in the estimated parameters of the demand model. Recursive estimation as a method of testing parameter changes in regression relationships was first introduced by Brown, et.al., (1975). Dufour (1982) later extended the approach and presented an exploratory methodology of data analysis to allow the assessment of parameter instability in econometric models. The

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[3] Rausser, G.C., Y. Mundlak, and S.R. Johnson,"Structural Change, Updating, and Forecasting", In New Directions in Econometric Modeling and Forecasting in U.S. Agriculture, edited by G.C. Rausser, (New York: Elsevier Science Publishing Co., 1983) pp. 659-666.

exploratory approach for testing whether structural change has occurred involves recursive estimation of a given demand model and the analysis of the corresponding standardized prediction errors called "recursive residuals".

Dufour differentiated the exploratory approach with those of what he calls "overfitting" procedures for testing parameter instability over time as done by Chow (1960), Quandt (1960), Farley and Hinich (1970), Cooley and Prescott (1973). These "overfitting" procedures involves "nesting a model into a more general one, by adding parameters and then performing significance tests on the added parameters." In order to detect patterns of parameter instability in the U.S. demand for livestock products, the exploratory approach suggested by Dufour (1982) is used in this study. The patterns of instability of the demand parameters are detected by considering the patterns of the recursive residuals that is revealed by the analysis.

4.4.1 Recursive Estimation[4]

This section presents a brief review of the exploratory approach in testing structural change in economic models. The discussion of the theory and procedure draws heavily on the work of Brown, Durbin, and Evans (1975) and Dufour

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[4] Recursive estimation is considered a special case of Kalman filtering, a technique used by Chavas (1983) to study structural change in the U.S. demand for meat.

(1982). The details of recursive least squares is also discussed in Harvey (1981).

Instability patterns in regression coefficients of a demand model maybe detected by performing recursive estimation of the demand function. The parameters of a linear demand equation is estimated recursively by using the first K observations to generate an initial estimate of the parameter vector, β. The model is then updated using a recursive updating formula which allows the estimation of β_r, (r = K+1, ..., T) parameter estimates. Recursive least squares allows the analyst to track the changes in the estimator over time. Also, under classical assumptions, the procedure allows the estimation of a set of uncorrelated recursive residuals which can be used to test parameter stability. Given T total observations, (T-K) estimates of the vector β are generated and correspondingly (T-K-1) one-step ahead recursive residuals are estimated.

Given a linear demand function with the following general form,

$$(4.1) \qquad Y_t = X'_t\, \beta_t + u_t$$

$$t = 1,2,\ldots, T; \quad u \sim N[0, \sigma^2_t\, I\,]$$

where Y_t is the observation in the dependent variable at period t, X_t is the column vector of observation on K non-stochastic regressors, β_t is a K component vector of regression coefficients (β is subscripted to indicate the hypothesis of parameter variation over time), u_t are assumed to be independently and normally distributed with zero mean and variance σ^2_t .

The null hypothesis to be tested is

$$(4.2) \qquad H_0 = \beta_K = \beta_{K+1} = \ldots = \beta_T = \beta$$

Under H, equation (4.1) follows the classical linear regression model with constant parameters.

$$(4.3) \qquad Y = X\beta + u \qquad\qquad u \sim N(0, \sigma^2_t\ I)$$

where

$$Y = (y_1, y_2, \ldots, y_T)'$$
$$X' = [x_1, x_2, \ldots, x_T]$$
$$u = (u_1, u_2, \ldots, u_T)'$$

The ordinary least squares (OLS) estimates based on T observations are given by

$$(4.4) \qquad \hat{\beta} = (X'X)^{-1} X'Y$$

By recursive estimation, the following sequence of estimates are generated

$$(4.5) \quad \hat{\beta} = (X'_r \; X_r)^{-1} \; X'_r \; Y_r \qquad r = K, K+1, . . . , T$$

where

$$X'_r = [\, x_1 \; , . . . , \; x_r \,], \quad Y'_r = [\, y_1 \; , . . . , \; y_r \,]$$

Using subsequent observations, the β coefficients denoted by β_K , β_{K+1} , . . . , β_T are generated without the matrix inversion implied in equation (4.5).

Following Harvey's notation, the updating formula has the the following form:

$$(4.6) \quad \beta_r = \beta_{r-1} + (X'_r \; X_r)^{-1} \; x_r (y_r - x'_r \; b_{r-1})/f_r$$

and

$$(4.7) \quad (X'_r \; X_r)^{-1} = (X'_{r-1} \; X_{r-1})^{-1} - (X'_{r-1} \; X_{r-1})^{-1} * x_r \; x'_r (X'_{r-1} \; X_{r-1})^{-1}/f_r$$

where

$$f_r = 1 + x'_r \; (X'_{r-1} \; X_{r-1})^{-1} \; x_r \qquad r = K+1, . . . , T$$

Equation (4.6) can be written as

$$(4.8) \quad \beta_r = \beta_{r-1} + (X'_{r-1} \; X_{r-1})^{-1} \; x_r \; v_r \; /f_r$$

where v_r is the one-step ahead prediction error. Hence, v_r

is considered to contain all the new information required to update the estimate of the regression parameters. Using the the first K observations, β_K is estimated using equation (4.5). β_K is then updated using equation (4.8). Note that the final estimator β_T is the same as those estimated by ordinary least squares using the T observations.

The sequence of regression estimates provides useful information about the likely instabilities of the parameters over the whole time period. The testing of instabilities in the sequence of regression estimates is facilitated by knowing some information about the behavior of the sequential regression estimates under the null hypothesis and then finding related statistics with already known distributions. To do this, Dufour(1982) starts by generating standardized prediction errors and several steps ahead recursive residuals and then constructing a number of related statistics to assess the significance of the instability patterns identified.

The standardized prediction errors are derived by first computing for each $r = K + 1, \ldots, T$, the predicted value of Y_r using the estimated β from the r-1 observations. the corresponding one-step ahead prediction errors are then calculated as follows:

$$(4.9) \qquad v_r = y_r - x'_r \hat{\beta}_r$$

$$r = K+1, \ldots, T$$

By doing this the predictive performance of the model is simulated by forecasting each data point in the sample with parameter estimates based on the preceding observations.

It can be shown that under the null hypothesis, the forecast error (v_r) has zero mean and variance $\sigma^2 d^2{}_r$ where d_r is a scalar function of the regressors defined as

$$(4.7) \qquad d_r = [\,1 + x'_r\,(X'_{r-1}\,X_{r-1})^{-1}\,x_r\,]^{1/2}$$
$$r = K+1, \ldots, T$$

The standardized prediction errors are estimated by dividing the estimated forecast error (v_r) by the scalar function d_r. That is,

$$(4.8) \qquad w_r = v_r / d_r \qquad\qquad r = K+1, \ldots, T$$

Under H_0, it is shown[5] that

$$E(\,w_r\,w_t\,) = 0 \quad \text{for} \quad r \neq t$$

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[5] See A.C. Harvey, Econometric Analysis of Time Series, (New York: John Wiley and Sons, 1981), pp. 55-56.

and w_{k+1}, ... w_T are independently and normally distributed with zero mean and variance σ^2 .

4.4.2 Recursive Residual Analysis

Under the null hypothesis of constant parameters, the standardized prediction errors (w_r) are independently and normally distributed with mean zero and variance σ^2. Given that parameter variation would disturb the stochastic properties of the recursive residuals, Dufour suggests testing for departures from this null distribution.

Before formal significance tests are conducted, Dufour and Brown, et.al., suggest listing and graphing the sequence of statistics derived from the recursive estimation. The statistics include 1) the recursive estimates of regression coefficients, 2) prediction errors (one and several steps ahead), 3) the recursive residuals, 4) standardized first differences of recursive estimates of regression parameters.

By graphing the recursive estimates of the regression parameters, the direct effect of each data point on the estimated value of each coefficient as well as the nature of the variations will be apparent. Dufour also suggests the examination of the empirical distribution of each set of coefficients as well as the corresponding variances, and coefficients of variations to determine the importance of the variations. Particular jumps and trends inside the sequences as likely signs of parameter instability. The significance of the variations may be determined by constructing confidence intervals for the recursive parameter estimates.

Under the null hypothesis, the recursive residuals are expected to be white noise with zero mean. By graphing the sequence of recursive residuals, parameter instability may be indicated by systematic tendencies to over-predict or under-predict, break points and sudden jumps, as well as runs of over-prediction or under-prediction. The graph of the series of k-steps ahead ($k \geq 2$) recursive residuals may also be examined and compared with the one-step ahead recursive residuals to determine the types and timing of structural shifts.

Also, the series of backward recursive residuals maybe compared with the forward recursive residuals to test whether there was structural shift at the beginning of the sample period. Under the null hypothesis, the standardized first differences of the recursive estimates are independent and normally distributed with zero mean and variance σ^2. Where the recursive residuals are not very revealing of instability patterns, the series of their first differences may show different sign patterns, thereby indicating some possible instabilities and break points in the parameters.

4.4.2.1 Significance Tests

Under the null hypothesis of constant regression coefficients, the recursive residuals are normally distributed with zero mean and variance σ^2. Thus, if β_t is constant up to $t = t_1$ and varying thereafter, the recursive residuals w_r, will have zero mean only up to t_1, and non-zero mean after period t_1. The behavior of the recursive residuals are considered to indicate temporal stability or instability of the estimated coefficients.

4.4.2.1.1 CUSUM and CUSUMSQ Tests

Brown, Durbin, and Evans (1975) developed two significance tests based on the recursive residuals. The first one, called the CUSUM test, is based on the graph of the following statistic against time,

$$(4.9) \qquad W_r = (1 / \hat{s}) \sum_{t=k+1}^{r} w_t$$

$$r = k+1, \ldots, T$$

where

$$\hat{s}^2 = \Sigma (w_t - \bar{w})^2 / (T-K-1)$$

When there is a structural break, a tendency for a disproportionate number of the recursive residuals having the same sign will be evident. The cumulative effect of this tendency will be shown in W_r moving away from the horizontal axis. The point at which the structural break occurs is indicated by the beginning of a secular increase or decrease in W_r.

That is, under Ho, the $E(Wr) = 0$; the plot of W_r should then be distributed around zero, if the β are stable. To test for the departure from the mean value, the probabilistic bounds for the path of W_r may be estimated. This boundary would be symmetrically above and below the line $W_r = 0$, so that the probability of crossing the boundary is α, the required significance level.

The equation of the boundary lines is given by Brown, Durbin, and Evans (1975) and Harvey (1981) to be as follows:

$$(4.10) \quad W = \pm \{ a(T-K)^{1/2} + 2a(r-K)/(T-K)^{1/2} \}$$

where $a = 0.948$ for 5 percent significance level and 0.85 for 10 percent significance level(Brown,et.al., p. 154).

If W_r crosses the boundary, the null hypothesis of constant parameters is rejected, indicating a structural change. According to Brown,et.al., the CUSUM test is used to detect systematic movements in β_r. For haphazard movements in the β_r, Brown, et.al., proposed a second test based on the recursive residuals called the CUSUMSQ test.

The CUSUMSQ test uses the squared recursive residuals, and is based on the plot of the values for

$$(4.11) \qquad S_r = \sum_{t=K+1}^{r} w_t^2 \Big/ \sum_{T=K+1}^{T} w_t^2$$

$$r = k+1, \ldots, T$$

The values of S_r lie between zero and one ($S_r = 0$ if $r < k+1$ and $S_r = 1$ if $r=T$).

The expected value of S_r , $E(S_r) = (r-k)/(t-k)$. The null hypothesis of constant parameters is rejected if if the plot of S_r crosses the boundary based on the level of the test. The boundary lines are defined as

$$(4.12) \qquad (r-k)/(t-k) \pm C$$

For a given significance level, α, the value of C is found by entering the table given by Durbin (1969) (Table 1, p.4) at $n = 1/2(t-k)-1$ and $1/2\alpha$.
According to Dufour, the CUSUM and CUSUMSQ tests are similar to "goodness-of-fit" tests because they are used against a wide variety of alternatives.

The plot of W_r can be expected to cross the probabilistic boundary when the recursive residuals tend to be positive (or negative) during some sub-periods as a consequence of particular large underpredictions (or overpredicttions). On the other hand, the plot of S_r can be expected to cross the probabilistic boundary during the subperiods when the recursive residuals are very large.

Dufour pointed out some weaknesses of the CUSUM and CUSUMSQ tests. First, Dufour suggested that the periods where the CUSUM plots cross the probabilistic boundaries may not generally coincide with the points of discontinuity in the regression coefficients. Hence, the plot of the recursive residuals may have to be used to complement the analysis of the plot of the CUSUM values. A second weakness involves the approximate nature of the distribution assumed under the null hypothesis. Also, the table given by Brown, et.al., only includes a small number of significance levels, thus, the computation of marginal significance levels can be potentially burdensome.

4.4.2.1.2 Location Tests

To test for monotonic type of instability as likely to be indicated by systematic under-prediction (or over-prediction), Dufour suggested testing the null hypothesis $E(w_r) = 0$ versus an alternative hypothesis $E(w_r) > 0$ or $E(w_r) < 0$, $r = K+1, \ldots, T$. The test is a form of a t-test based on the following statistic

$$(4.13) \qquad t = (T - K)^{1/2} \; w / s_w$$

where

(4.14) $$w = \sum_{r=K+1}^{T} w_r \; / \; (T-K)$$

and

(4.15) $$s_w^2 = \sum_{r=K+1}^{T} (w - \bar{w}_t)^2 \; / \; (T-K-1)$$

Under H_o , the values of t follows a Student -t distribution with (T-K-1) degrees of freedom.

The null hypothesis of $E(w_r) = 0$ is rejected if t > c, where the value of c depend on the level of the test.

Dufour suggests the t-test as a check against systematic under-prediction or over prediction.

In general, the t-test is based on the average of the expected standardized forecast errors,

(4.17) $$E(\bar{w}) = \sum_{r=K+1}^{T} E(w_r) \; / \; (T-K)$$

$$H_o \; : \; E(\bar{w}) = 0$$

H_1 : $E(\bar{w})$ is not equal to zero

(4.18) If $E(w_{K+1}) = E(w_{K+2}) = \ldots = E(w_T) = 0$

a t-test based on (4.14) is considered to be uniformly most powerful (one sided test) or uniformly most powerful unbiased (two sided test) among the tests based on the recursive residuals (Dufour, p.60).

4.4.2.1.3 <u>Linear Rank Tests</u>

Under the null hypothesis of constant regression coefficients, the recursive residuals are considered to be independent and symmetrically distributed with median equal to zero[6]. Dufour suggests the use of any test within the family of linear rank tests to test for symmetry around the zero median under H_0. An advantage of the rank test is the fact that it does not require the estimation of the variance σ^2. Given the following,

$$n = T-K \tag{4.19}$$

$$Z = w_{K+1}, w_{K+2}, \ldots, w_T$$

a linear rank test for symmetry around zero may be employed using the statistic

$$S = \sum_{t=1}^{n} u(Z_t)\, a_n(R_t^+) \tag{4.20}$$

where u(.) is an indicator function so that

$$u(z) = 1 \quad \text{if} \quad z > 0$$
$$= 0 \quad \text{if} \quad z < 0$$

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[6] Under the normality assumption, the mean and median of the recursive residuals are equal. (Dufour, 1982, p. 61).

and

$$R_t^+ = \sum_{i=1}^{n} u(Z_t - Z_i)$$

is the rank of Z_t when $Z_1, \ldots, Z_n$ are ranked in increasing order.
a_n (.) is a score function used to transform the rank R_t^+.

(4.21) If $a_n(r) = 1$, $S = \sum_{t=1}^{n} u(Z_t)$

(4.22) If $a_n(r) = r$, $S = \mathrm{SUM}_{t=1}^{n} u(Z_t) R_t^+$

In (4.21), S is equal to the number of non-negative Z'_ts (Sign Test); while in (4.24) S is the sum of the ranks associated with the non-negative Z'_ts (Wilcoxon Test).

When the underlying distribution is normal, the Wilcoxon test (based on 4.22) is considered to be relatively powerful. However, in cases where the t-test is optimal, the efficiency of the Wilcoxon test relative to the t-test is about 0.96 (Dufour, 1982, p. 63). Since there is a tendency to overestimate σ^2, the Wilcoxon test is considered to be potentially more powerful against certain alternatives, due to the fact that it does not require an estimate of σ^2 .

Also, Dufour, favors the use of the rank tests because of their robustness to non-normality and the effects of outliers.

4.4.2.1.4 Modified Von Neumann Ratio Test

Parameter instability also leads to situations where the means of the cross products $Z^K{}_t = w_t w_{t+K}$, $t = K+1,\ldots,T-K$ (where $1 \leq K \leq T-K-1$) is not equal to zero (Dufour, 1982, pp. 52-55).

To test for instability in the demand parameters we, therefore, test whether Z_{Kt} has a zero mean. For this test, Dufour suggested the modified Von Neumann Ratio (VR) statistic. VR is defined as follows:

$$(4.23)\quad VR = (n-1)^{-1} \sum_{t=K+1}^{T-1} (w_{t+1} - w_t)^2 \div n^{-1} \sum_{K+1}^{T} w_t^2$$

where n=T-K. VR is considered to be an exact parametric test of the null hypothesis $E(w_t w_{t+1}) = 0$, $t= K+1,\ldots,T-1$. (Dufour, 1982).

4.4.2.1.5 Test for Heteroscedasticity

Given some information about the possible points of structural break, a test of parameter instability between two subperiods may be tested. Dufour(1982) suggested the test for heteroscedascity for this purpose. Following Dufour's notation, the test involves dividing the recursive residuals into two subperiods I_1 and I_2, with m_1 and m_2 elements and computing the following statistic:

$$(4.24)\quad R = (m_1/m_2)\ (\ \Sigma_{t\ \varepsilon\ I_2} w^2{}_t\ /\ \Sigma_{t\ \varepsilon\ I_1}\ w^2{}_t\ )$$

Under H_0, R follows an F distribution with (m_2, m_1) degrees of freedom. H_0 is rejected at level α if $R \geq F_{\alpha/2}$ or $R \leq F_{1-(\alpha/2)}$ where $P[F(m_2, m_1) \geq F_\alpha] = \alpha$ for a two sided test.

4.4.2.1.6 Quandt's Log Likelihood Ratio Test

If the CUSUM and CUSUMSQ tests led to the rejection of the null hypothesis of constant parameters, the Quandt's log likelihood ratio test may be used to determine the timing of structural change. This ratio is defined by Brown and Durbin (1975). For each r, from r=K+1 to r=T-K-1, the following statistic is calculated:

$$(4.25)\quad q = 1/2\ r \log s_1^2 + 1/2\ (T-r) \log s_2^2 - 1/2\ T \log s^2$$

where $s^2{}_1$ is the ratio of the residual sum of squares to #

of observation when the regression is fitted to the first r observations, s^2_2 is the ratio of the residual sum of squares to the number of observations when the regression is fitted to the remaining T-r observations and, s^2 is the ratio of the residual sum of squares to the number of observations when the regression is fitted to the whole set of T observations. The timing of the structural break is indicated by the point at which q_r reaches its minimum. Brown, Durbin and Evans indicated that if the plot of q_r against time is markedly jagged, the change in the parameters is sharp and discrete. A relatively smooth likelihood surface is considered to indicate an abrupt change.

4.2.2.3.7 Runs Test

Given that shifts in the regression parameters tend to be manifested through runs of either under-predictions or over-predictions in the recursive simulation process, a test that considers the sequence of the signs of

$$s(w_{K+1}), \ldots, s(w_T)$$

where

$$s(x) = + \quad \text{if } x > 0$$

$$s(x) = - \quad \text{if} \quad x < 0$$

is suggested. This test first involve counting the number R of runs. A few number of R is taken as an evidence of a few parameter shifts during the time period considered.
It is showed that $R - 1 \sim B_1 \quad (N-1, 1/2)$
where $N = T - K$. Hence, the $P[\, R < c\,]$ for any c may be computed.

The case where there is long run of under-prediction (or over-predictions), an indication of a shift after a given period may also be considered. In this case, the analyst has to determine the length of the longest run (with any sign) in the sequence. The probability of getting at least one run of this length or greater may be computed. If this probability is too low, (smaller than some critical point associated with a particular significance level α, the null hypothesis is rejected.

4.5 Specifying Parameter Variation in Demand Models

This section provides a brief review of approaches in specifying structural change in estimating demand models. A more thorough discussion of the econometrics of structural change can be found in Poirier (1976). Most of the applications of these approaches are in the context of quantity-dependent demand models. This study will attempt to incorporate the identified structural change based on the exploratory tests in the previous section in the context of inverse demand models for livestock products.

There are several approaches that can be used to incorporate structural change in commodity demand models. Depending on the nature of the structural shift, one approach may be more appropriate than others. This section gives a brief review of approaches that will be used to incorporate structural change in demand for meat.

4.5.1 Use of time trend

A time trend variable is often introduced in a demand model to represent the effects of continous change in tastes. There are, however, problems with this particular approach that should be considered. Variables such as prices and income are often highly correlated with time; hence, problems of multicollinearity may prevent the estimation of separate effects of the correlated explanatory variables. In cases of cyclical fluctuations and sudden changes, the use of time variable in a logarithmic demand specification might be unsatisfactory because inherent in the specification is the assumption that all factors not accounted for by the income and relative price variables are changing at a constant instantaneous percentage rate per unit of time. In a linear demand model, the coefficient of the time variable measures the rate of shift of demand in terms of annual units demanded, given prices and income. In either specification, the shift in demand is approximated by a smooth, steady, monotonic function of time.

4.5.2 Use of Flexible Trends

Instead of a steady monotonic shift in demand, a flexible trend that allows demand to shift at different rates and at different times may be used.[7] The flexible trend may be approximated by a cubic spline. A cubic spline is a special case of piecewise regression consisting of a series of cubic polynomials in time which has continous first and second derivatives.

The flexible trend is included in the specification of the demand model as follows:

$$(4.26) \quad P_t = \beta_0 + \beta_1 Q_t + \beta_3 Y_t + F(t) + e_t$$

where P, Q, represents prices and quantities, respectively

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[7] For a discussion of spline functions and its applications to the demand for coffee in the U.S., see Huang, C., J. Siegfried, and F. Zardoshty, "The Demand for Coffee in the United States, 1963-77," Quarterly Review of Economics and Business, 20 (Summer 1980), pp. 36-50.

of a commodity, Y is a measure of income and F(t) is the flexible trend. The trend is specified as a cubic spline by first dividing the time period into subperiods, namely $0 \leq t \leq k_1$; $k_1 \leq k_2$; and so on. The spline functions is expressed in the form

$$(4.27) \quad F(t) = b_0 + b_1 t + b_2 t^2 + b_3 t^3 + \Sigma\, c_i (t-k_i)^3 D_i$$

where the D_i represents dummy variables with value of zero during $t < k_i$ and equals one when $t \geq k_i$. The coefficients may be estimated by ordinary least squares.

4.5.3 Use of Dummy Variables

Abrupt or discontinous shifts in supply and demand can be accounted for by introducing dummy variables. These variables are used to represent qualitative information such as qualitative shifts over time or space (e.g., war or peace). Dummy variables take on a value of one for and after the critical year. This approach allows a single displacement of the intercept for the period beginning in the year in which the change occured. The effect of the shift is calculated by adding the coefficient of the dummy variable to the intercept coefficient.

Dividing the data set into intervals and the definition of dummy variables to represent the partitions is preferred over procedures which involves dropping some parts of the data set or estimating a function using the whole period without accounting for the interval shift. Suits (1957) indicated that unbiased regression coefficients are generated by the introduction of dummy variables under situation of abrupt or discontinous shifts in the data.

Brown (1952) employed a shift variable to represent the structural change which occured after World War II due to disturbances in the habits of consumers, introduction of new products and new technologies and effects of price controls.

4.5.4 Use of Interaction Variable

Interaction variables can be introduced if the structural change is believed to have an effect on the magnitude of the slope and shift coefficients. This variable forms a multiplicative term between the slope or shift variable and a dummy or time variable depending on whether the interaction involving the slope or shift variable is abrupt or gradual, respectively.

4.5.5 Varying Parameter Specification

The approaches considered above can be sufficient and appropriate when the structural change produces a discontinuous effect and that separate regression equations can be estimated for subsets of data to reflect the intercept and slope changes. However, when the structural change have a differential effect on the slope coefficient during the time period or for specific portions of the observations, more complex approaches may be required to account for the structural change in the model specification.

Rausser, Mundlak, and Johnson (1981) discussed the justifications for specifying parameter variation in time series regression analysis to capture the changes in the structural relationships between the dependent and the explanatory variables. Variables that cause structural change are often omitted in the specification of equations in classical regression analysis. Rausser, et. al., (1981) note that the excluded variables oftentimes are nonstationary and are correlated with the included variables; hence, the estimated effects of the latter can be expected to vary over time and are biased.

The framework for specifying variations in parameter is based on the discussion in Rausser, Mundlak and Johnson (1981). Given a single equation with one explanatory variable,

$$(4.28) \quad Y_t = \beta_t X_t + u_t$$

where

$$u \sim (0, \sigma^2_u), \quad E(u_t X_t) = E(u_t \beta_t) = 0$$

$$t = 1,2,....$$

The parameter β_t is subscripted to represent variations over time. The changes in β_t can be systematic or random.

Let

$$(4.29) \quad \beta_t = \beta_0 + L(X_t) + Z_t a_t + e_t$$

where

$$e \sim (0,\sigma^2_e), \quad E(e_t Z_t) = E[e_t L(X_t)] = 0$$

$$t = 1,2,......$$

The term Z_t represent the effect on the coefficient of variables not included in the system while $L(X_t)$ represents the effect of the variables in the system. Combining equations (4.28) and (4.29) gives

$$(4.30) \quad Y_t = \beta_0 X_t + L(X_t)X_t + a X_t Z_t + v_t$$

where

$$v_t = X_t e_t + u_t$$

The variable Z_t can be a zero-one indicator variable which allows a switch in the regression coefficient. The function $L(X_t)$ can be specified in terms of geometric distributed lag as follows

$$(4.31) \quad \beta_t = \beta_0 + \delta X_{t-1} + \delta X_{t-2} + \ldots + \phi Z_t + e_t$$

with $\delta < 1$. Multiplying equation (4.31) by δ and subtracting $\delta \beta_{t-1}$ from β_t, gives the following equation

$$(4.32) \quad \beta_t = \delta \beta_{t-1} + (1-\delta)\beta_0 + \delta X_{t-1} + \phi (Z_t - Z_{t-1}) + (e_t - \delta e_{t-1})$$

Note that equation (4.32) follows Rosenberg's specification. Since δ is between zero and one, the term $\delta \beta_{t-1}$ indicates a decay process. Note also that equation (4.30) has a heteroscedastic error term.

4.5.5.1 Continous Time Varying Parameter: Complex Legendre Polynomial

To allow continous variation in the parameters, the parameters may be specified as continous functions of time by using Legendre polynomials.[8] In a study of structural change in the retail demand for table beef and hamburgers, Cornell (1983) used Legendre polynomials to allow for continous variation in the retail demand parameters. The approach used by Cornell will be applied in this study in testing for continous variation in the parameters of the farm level demand for beef, pork, broilers and turkeys in the U.S.

This section briefly reviews the theory and specification of Legendre polynomials applied in estimating farm level demand for meat. The material is based on the presentation in Cornell (1983) and in Manetsch and Park (1981).

Legendre polynomials are orthogonal functions used to represent any continous function F(x) or F(t) over the interval (-1,1). For example, a continous function may be represented as

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[8] For a detailed discussion of the theory of Legendre polynomials, see Manetsch, T.J., and Park,G.L., Systems Analysis and Simulation with Application to Economic and Social Systems, Part I and II, Department of Electrical Engineering and Systems Science, Michigan State University, East Lansing, 1981. For an application in estimation of retail demand for meat, see Cornell, (1983)

(4.32) $F(x) = a_o P_o(x) + a_1 P_1(x) + ... + a_n P_n(x)$

for $-1 < x < 1$.

The polynomial functions are defines as follows

$Po(x) = 1$

$P1(x) = x$

$P2(x) = 1/2\ (3x^2 - 1)$

.

.

$P_{n+1}\ (x) = 1/n+1\ [\ (2n + 1)\ x\ P_n(x) - nP_{n-1}(x)]$

To make the polynomials orthogonal with respect to time, the functions are mapped into $0 < t < T$. The polynomials are transformed as follows

$P_o'(t) = 1$

$P_1'(t) = 2t/T - 1$

$P_2'(t) = 1/2\ [\ 3(2t/T - 1)^2 - 1\ ]$

.

$P_{n+1}'(t) = 1/n+1[(2n+1)(2t/T - 1)\ P_n'(t) - nP_{n-1}(2t/T-1)]$

The Legendre polynomials are introduced into the demand models as follows: Given a simple inverse demand model for the ith product:

$$(1)\quad P_{it} = \beta_{oi} + \beta_{iit} Q_{it} + \beta_j \sum_{j=1}^{k} Q_{jt} + c_i Y_t + e_t$$

where P_{it} is a (nx1) vector of observations on the real price of the ith commodity in time t, Q_{it} is a (nx1) vector of observation on the own-quantity of meat consumed per person, Q_{jt} is a (nxk) observation on per capita consumption of substitutes commodities, Y_t is a (nx1) vector of observation on real per capita disposable income, e_t is an (nx1) random vector , serially uncorrelated, and distributed with mean zero and covariance matrix $E(e_t, e'_t) = \sigma$. β_{oi}, β_{iit}, β_j, and c_i are the demand parameters to be estimated.

Initially, parameter variation is only allowed to occur in the own-quantity per capita consumption, Q_{it}. The coefficient β_{iit} is generated as follows:

$$(2)\quad \beta_{iit} = A_{oi} + A_{1i}\ P_o(t) + A_{2i}\ P_1(t) + \ldots + A_{ni}\ P_{n-1}(t)$$

$$(2)\quad \beta_{iit} = A_{oi} + \sum_{r=1}^{n} (A_{ri}\ P_{n-1}(t))$$

where $P_{n-1}(t)$ are the n-1 Legendre polynomials. Substitution of (2) into (1) gives:

$$(3) \quad P_{it} = \beta_{oi} + A_{oi} + \sum_{r=1}^{n} A_{ri} \; P_{n-1}(t) \; Q_{it} + \beta_j \sum Q_{jt} + C_i Y_t + e_t$$

where $\Sigma A_{ri} \; P_{n-1}(t) \; Q_{it}$ is an interaction variable in Q_{it}, Q_{jt}, and Y_t are the substitute and/or complement, and income variables, respectively. $A_{ri} \; P_{n-1}(t)$ is a time varying coefficient which can be estimated and tested under standard regression techniques. A demand model with a second degree polynomial in one explanatory variable can be estimated with the following specification:

$$(4) \quad P_{it} = A_0 + A_1 \; P_0(t) \; Q_{it} + A_2 \; P_1(t) \; Q_{it} + A_3 \; P_2(t) \; Q_{it} + \beta_j \sum_{j=1}^{n} Q_{jt} + C_i Y_t + e_t$$

The polynomials may be introduced in any of the explanatory variables that are considered to vary over time. The own-quantity flexibility for the ith commodity corresponding to the linear demand function in equation (4) can be generated as follows:

$$(5) \quad f_{it} = [\, A_1 \; P_0(t) + A_2 \; P_1(t) + A_3 \; P_2(t) \,] \; Q_{it}/P_{it}$$

As pointed out in Cornell (1983) and in Manetsch and Park (1981), the Legendre polynomials has the important property of finality of coefficients. That is, the addition of a higher degree polynomial in time will not change the coefficients previously estimated using a lower degree polynomial. Also, the polynomial introduced in the variables do not have to be in the same degree.

4.6 Summary

Structural change in demand is defined as any change in the parameter of the consumer's utility function. Since the utility function is not observable, empirical analysis of structural change due to change in preferences is carried out in a limited sense. The limited analysis of structural change involves the testing and estimating changes in the parameters of the derived demand function. The analysis of structural change in terms of changes in demand parameters has several important limitations. First, the demand parameters may change not only due to structural change but also because of possible model specification errors. Second, the analysis does not involve explicit investigation of causes of the structural change, actions relevant to the meat industry to affect preferences cannot be adequately addressed.

Although there are limitations in the analysis, the testing and estimation of parameter variation in the context of a forecasting model of U.S. livestock and poultry sector offer several benefits. After correcting for potential model misspecification, allowing the parameters to change over time will likely improve the historical fit and forecasting performance of the livestock and poultry model. Second, the analysis allows the determination of effects of observations on the recursive parameter estimates. In addition, one and several steps ahead recursive residuals are instructive tools in identifying the timing and patterns of parameter variation.

The recursive estimation may be used to analyze the patterns of changes in parameters of linear inverse demand models for beef, pork, broiler, and turkey. Estimated one-step ahead recursive residuals may be used in testing the significance of the parameter changes.

The identified parameter variation based on the exploratory analysis may be used in respecifying the inverse demand models estimated in chapter 3 to account for the changes. There exist several approaches to specify parameter variation in demand models. For the purposes of the study, approaches that allow abrupt and gradual continous parameter variation are considered. The exploratory analysis and approaches in specifying parameter variation in demand models are applied in the following chapter.

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CHAPTER 5

EMPIRICAL RESULTS OF PARAMETER STABILITY ANALYSIS OF FARM LEVEL DEMAND FOR LIVESTOCK AND POULTRY

5.1 Results of Recursive (Sequential) Estimation and Recursive Residual Analysis

Recursive estimation as discussed in section 4.2.2 was applied to determine the stability over time of the farm level demand parameters for livestock and poultry. The pattern of the recursive estimates of the coefficients of the inverse demand models are analyzed, taking note of particular trends and discontinuities. The recursive parameter estimates are used as a descriptive device in determining the effects of different observations in a sequential updating process. Since the recursive parameter estimates tend to be highly correlated even under the null hypothesis of parameter stability,[1] the associated sequences of standardized recursive residuals are used in conducting an exploratory analysis to search for patterns indicative of possible structural shifts. The simple statistical properties of the one-step ahead recursive residuals make them a useful tool in conducting significance tests of parameter instability. As discussed in Chapter four, the statistical properties of the recursive residuals under the

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[1] Dufour (1982) showed that the recursive estimates follow a heteroscedastic random walk process.

null hypothesis of parameter stability are similar to the BLUS residuals[2] and therefore can be used for descriptive analysis and for the construction of various significance tests.

In particular, if the demand parameters are stable over time, the corresponding recursive residuals have a zero mean and a scalar covariance matrix. That is, under the null hypothesis of constant parameters, the recursive residuals have the following properties:[3]

(1) $E(w_r) = 0$

(2) $E(w^2{}_r) = \sigma^2$

(3) $E(w_r w_s) = 0 \quad r \neq s$

Thus, the recursive residuals under the null hypothesis of constant parameters are a normal white noise series. Structural change in demand is expected to influence the behavior of the corresponding recursive residuals. For instance, an abrupt and sudden shift in the demand parameters at some point r* in the sample period will result in an abrupt increase in the size of the recursive residuals and/or a tendency to overpredict or underpredict prices (dependent variable) for r > r*. A systematic drift in one

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[2] See Theil (1971,chapter 5).

[3] See Brown, Durbin, and Evans (1975) pp. 151-153; Also see Harvey (1981), pp. 55.

or more of the demand parameters often result to a systematic tendency to overpredict or underpredict.
In this section, the standardized recursive residuals are used in performing an exploratory analysis to look for patterns which indicate possible structural breaks in the demand for beef, pork, broiler and turkey.

For each model considered, the null hypothesis is that of constant parameters. A general alternative hypothesis is that of parameter instability due to structural change in demand. More specific alternative hypothesis such as gradual,abrupt, and/or continous changes in the demand parameters are also tested.

For each model considered, the forward recursive estimates of each coefficient, as well as the one-step recursive residuals are reported. The recursive estimates for each coefficient and recursive residuals are plotted. The first two tests applied in the analysis were the BDE's cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests which are based on the one-step ahead recursive residuals.[4] With a structural change, the standardized recursive residuals will have a non-zero mean and the CUSUM and CUSUMSQ can be used to test for structural change. The CUSUM and CUSUMSQ statistics for the four commodities are presented graphically with confidence

[4] For applications of the CUSUM and CUSUMSQ test to demand studies, see Martin and Porter (1985); Hassan and Johnson (1979); Moschini and Mielke (1984).

boundaries estimated based on a predetermined significance level. If the plot of the CUSUM and CUSUMSQ crosses the confidence boundary, then the null hypothesis of constant parameters is rejected. The nonparametric tests suggested by Dufour (1982a) are also applied in the analysis.

Table 5.1 presents the test statistics for the demand model for the four commodities. The forward one-step recursive residuals are used to compute the test statistics. The t-statistic based on the one-step recursive residuals are estimated for each equation to test whether the residuals have a zero mean. The marginal significance levels associated with the test statistics are also reported wherever possible. In discussing the results, the traditional five percent level is used as the benchmark in evaluating the statistical significance of the results.

5.1.1 Beef Demand

The recursive parameter estimates for the beef demand equation with k= 1955-1961 are listed in Table 5.2; those based on demand equation with k=1960-1968 and k=1970-79 are listed in Table 5.3 and Table 5.4, respectively. The most striking feature is the declining and increasing trend (in absolute value) in the estimates of coefficients on the beef per capita consumption (BFPC) and poultry (broilers and turkeys) per capita consumption (POULPC), respectively.

Table 5.1 Test Statistics of Parameter Stability Based on One-Step Ahead Recursive Residuals

Statistic	Cattle	Hog	Broiler	Turkey
Number of Residuals	25	25	24	24
BDE's Tests				
CUSUM	0.88 n.s.	0.74 n.s.	0.78 n.s.	0.54 n.s.
CUSUMSQ	0.6110 (0.05)	0.5056 (0.05)	0.3293 (0.05)	0.1701 n.s.
Global Location Tests				
t	-3.6058 (0.005)	2.4116 (0.025)	2.5738 (0.05)	0.0489 n.s.
Wilcoxon's Rank Sum	60.00	81.00	233	161
T*	-2.76 (-0.0029)	-2.19 (0.0143)	2.37 (0.0089)	0.3143 n.s.
Serial Dependence Tests				
Von Neumann (modified)	0.2370 (0.05)*	0.5129 (0.05)*	1.7013 n.s.**	1.5014 n.s.**
Heteroscedasticity test	61.4434 (0.05)	11.3217 (0.05)	3.6063 (0.05)	1.6298 n.s.

* The VR value is below the 5 % significance point (1.344) for n-K = 25 in the one-tailed test against positive serial correlation.

** The VR value is above the 5% significance point (1.33) for n-K = 24 in the one-tailed test of positive serial correlation and is also below the 5% significance point (2.677) for the one-tailed test against negative serial correlation.

Table 5.2 Beef Inverse Demand Equation: Recursive Parameter Estimates, 1955-1985

Year	Constant	BFPC	PKPC	POULPC	DINC	R
1955-62	26.6828	-0.8650	-0.0655	-0.1236	0.0390	0.94
		(0.1384)	(0.1320)	(0.1553)	(0.0126)	
1955-63	28.4426	-0.8766	-0.0664	-0.1173	0.0386	0.96
		(0.1124)	(0.1153)	(0.1335)	(0.0109)	
1955-64	34.5974	-0.8559	-0.0178	-0.0404	0.0324	0.97
		(0.1087)	(0.1014)	(0.1035)	(0.0085)	
1955-65	38.3544	-0.7586	0.0837	0.0593	0.0224	0.95
		(0.088)	(0.074)	(0.0787)	(0.0047)	
1955-66	36.7371	-0.7728	0.0684	0.0456	0.0244	0.95
		(0.0910)	(0.0761)	(0.0812)	(0.0047)	
1955-67	41.1921	-0.7348	0.0255	0.0592	0.0218	0.94
		(0.091)	(0.072)	(0.0850)	(0.0045)	
1955-68	39.6251	-0.7477	0.0399	0.0418	0.0229	0.94
		(0.0851)	(0.0661)	(0.0766)	(0.0040)	
1955-69	37.5811	-0.7655	0.0527	0.0275	0.0244	0.92
		(0.0937)	(0.0728)	(0.0845)	(0.0043)	
1955-70	38.2476	-0.7624	0.0440	0.0227	0.0243	0.92
		(0.090)	(0.067)	(0.0800)	(0.0040)	
1955-71	40.6370	-0.7216	0.0021	0.0258	0.0227	0.91
		(0.0843)	(0.0585)	(0.0820)	(0.0039)	
1955-72	40.5659	-0.7441	-0.0029	0.0184	0.0238	0.91
		(0.0745)	(0.0566)	(0.0792)	(0.0034)	
1955-73	39.0844	-0.6234	0.0375	0.0772	0.0177	0.92
		(0.0529)	(0.0593)	(0.0827)	(0.0019)	
1955-74	39.4371	-0.6173	0.0371	0.0880	0.0171	0.92
		(0.0523)	(0.0592)	(0.0816)	(0.0018)	
1955-75	40.0990	-0.6089	0.0152	0.0767	0.0173	0.91
		(0.0491)	(0.0440)	(0.0774)	(0.0018)	
1955-76	39.9531	-0.6168	0.0229	0.0749	0.0174	0.93
		(0.0440)	(0.0386)	(0.0753)	(0.0016)	
1955-77	40.4798	-0.6212	0.0538	0.1578	0.0153	0.81
		(0.0764)	(0.0664)	(0.1286)	(0.0028)	
1955-78	39.5013	-0.5456	0.0685	0.1310	0.0128	0.74
		(0.0807)	(0.0756)	(0.1465)	(0.0030)	
1955-79	39.0009	-0.3922	0.0271	-0.0423	0.0108	0.68
		(0.0625)	(0.0839)	(0.1481)	(0.0033)	
1955-80	40.3267	-0.3279	-0.0238	-0.1653	0.0109	0.57
		(0.0644)	(0.0916)	(0.1576)	(0.0037)	
1955-81	37.7177	-0.2822	-0.0036	-0.3498	0.0127	0.46
		(0.0710)	(0.1042)	(0.1629)	(0.0041)	
1955-82	33.6538	-0.2361	-0.0551	-0.4765	0.0141	0.45
		(0.0733)	(0.1032)	(0.1528)	(0.0042)	
1955-83	32.6994	-0.2435	-0.0651	-0.5480	0.0147	0.45
		(0.0771)	(0.1094)	(0.1576)	(0.0045)	
1955-84	30.7820	-0.1779	-0.0882	-0.5314	0.0121	0.41
		(0.0773)	(0.1177)	(0.1701)	(0.0047)	
1955-85	29.2530	-0.1477	0.1092	-0.5792	0.0118	0.45
		(0.0804)	(0.1243)	(0.1788)	(0.0049)	

Numbers in parenthesis are standard errors.

Table 5.3 Beef Inverse Demand Equation: Recursive Parameter Estimates, 1960-1985

Year	Constant	BFPC	PKPC	POULPC	DINC	R
1960-69	36.8963	-0.7559	0.0691	-0.0261	0.0248	0.83
		(0.1925)	(0.1325)	(0.2665)	(0.0075)	
1960-70	37.9067	-0.7460	0.0550	-0.0591	0.0248	0.84
		(0.1733)	(0.1108)	(0.2040)	(0.0069)	
1960-71	40.5897	-0.6712	-0.0027	-0.0795	0.0225	0.83
		(0.1391)	(0.0789)	(0.1962)	(0.0061)	
1960-72	40.7271	-0.7202	-0.0100	-0.0669	0.0244	0.83
		(0.1189)	(0.0761)	(0.1899)	(0.0053)	
1960-73	38.2607	-0.5762	0.0179	0.0278	0.0174	0.91
		(0.0748)	(0.0788)	(0.1912)	(0.0028)	
1960-74	38.7090	-0.5714	0.0158	0.0494	0.0167	0.90
		(0.0737)	(0.0778)	(0.1872)	(0.0026)	
1960-75	38.9570	-0.5662	0.0068	0.0414	0.0168	0.90
		(0.0641)	(0.0544)	(0.1732)	(0.0026)	
1960-76	38.8277	-0.5815	0.0250	0.0081	0.0175	0.92
		(0.0580)	(0.0453)	(0.1612)	(0.0022)	
1960-77	40.0421	-0.6157	0.0500	0.2044	0.0145	0.75
		(0.1072)	(0.0838)	(0.2924)	(0.0040)	
1960-78	38.5097	-0.5114	0.0744	0.0269	0.0134	0.66
		(0.1080)	(0.0935)	(0.3161)	(0.0044)	
1960-79	37.6360	-0.3913	0.0651	-0.2941	0.0145	0.66
		(0.0729)	(0.0967)	(0.2365)	(0.0045)	
1960-80	38.6856	-0.3551	0.0421	-0.4741	0.0162	0.59
		(0.0743)	(0.1018)	(0.2261)	(0.0047)	
1960-81	36.9255	-0.3446	0.0787	-0.6915	0.0192	0.56
		(0.0785)	(0.1056)	(0.2005)	(0.0046)	
1960-82	35.1172	-0.3448	0.1140	-0.7813	0.0206	0.59
		(0.0778)	(0.0959)	(0.1678)	(0.0043)	
1960-83	34.8299	-0.3415	0.1262	-0.8625	0.0216	0.61
		(0.0813)	(0.1000)	(0.1678)	(0.0044)	
1960-84	32.4587	-0.2742	0.1517	-0.8447	0.0191	0.53
		(0.0873)	(0.1127)	(0.1899)	(0.0049)	
1960-85	31.6616	-0.2614	0.1735	-0.9114	0.0195	0.57
		(0.0918)	(0.1184)	(0.1969)	(0.0052)	

Numbers in parenthesis are standard errors

Table 5.4 Beef Inverse Demand Equation: Recursive Parameter Estimates, 1970-1985

Year	Constant	BFPC	PKPC	POULPC	DINC	R
1970-80	97.7432	-0.5440	-0.1346	-0.5093	0.0087	0.74
		(0.1495)	(0.2061)	(0.3279)	(0.0084)	
1970-81	81.0353	-0.4946	-0.0115	-0.8151	0.0147	0.69
		(0.1571)	(0.2028)	(0.2721)	(0.0080)	
1970-82	68.8042	-0.4644	0.0717	-0.9246	0.0176	0.72
		(0.1459)	(0.1581)	(0.2142)	(0.0065)	
1970-83	74.0192	-0.4817	0.0679	-0.9965	0.0179	0.74
		(0.1451)	(0.1583)	(0.2024)	(0.0065)	
1970-84	90.7840	-0.5225	0.0295	-1.0016	0.0142	0.73
		(0.1488)	(0.1604)	(0.2089)	(0.0061)	
1970-85	96.3519	-0.4798	0.1195	-1.0104	0.0101	0.83
		(0.1541)	(0.1980)	(0.2058)	(0.0071)	

Numbers in parenthesis are standard errors

The recursive coefficients on pork per capita consumption (PKPC) in the beef demand model appear to be small and were relatively stable over the time period of analysis. However, the signs are contrary to expectations in most years. The recursive estimates of the coefficient on the income variable appear to have slightly declined over the period.

From the forward recursive estimates of the coefficient on per capita beef consumption (BFPC) based on the equations estimated beginning 1960, the decline in the absolute value of the coefficient become most evident when the equation is estimated up through 1973. This can be considered a possible discontinuity in the coefficient on BFPC. This coefficient stabilizes at around -.6 starting in 1973 through 1977. It then declined to -.39 in 1979 and then to -.34 and -.27 in 1983 and 1984, respectively.

From the equation estimated from 1960 through 1970, the coefficient on BFPC has a value of -.746 (see Table 5.3). The same specification estimated from 1970 to 1984 (see Table 5.4) show a relatively lower magnitude (in absolute values) of -.5225. On the other hand, the coefficient on poultry per capita consumption, POULPC, increased (in absolute value) from -.0591 to -1.0016 during the same period.

The recursive estimates of the coefficients on pork per capita consumption,PKPC, stayed very small during the whole time period, with a sign contrary to expectations in most years. The coefficient on real personal disposable income per capita (DINC) averaged around .02 until 1977 when it dropped slightly to .0145 (equation estimated in 1960-77, table 5.3). It increased again to the .02 level starting in 1980 (equation for 1960-80) through 1985 (equation for 1960-85).

The recursive residuals for the beef demand model are listed in Tables 5.5 to 5.7. From the one-step ahead recursive residuals based on equation with k=1955-1960 (Table 5.5), a discontinuity is evident starting in 1977 when the residual increased to -8.09 from -0.473 in 1976. Two periods with very different patterns are identified: 1961 to 1976 and 1977 to 1985. They differ in two ways. First, the average size of the residuals is much greater in the second period than in the first period. The residuals in all the 9 years (1977-85) are more than twice as large in absolute value as the largest residual in the first period; the most "outlying" residual is in 1984 and 1985. Second, there is a tendency to overpredict in the second period (indicated by the negative residuals). Although there are 10 overpredictions in the first period, their average size is relatively small.

Statistically, the forward one-step ahead recursive residuals (based on k=1955-1960) deviate from what we expect from the null hypothesis of constant regression

Table 5.5 Beef Inverse Demand Equation: Recursive Residual Analysis
k = 1955-1960, r = 1961, 1962, ..., 1985

Year	Actual Value $/cwt.	Recursive One-Step Ahead Forecast $/cwt.	Forecast Error $/cwt.	Variance of Forecast Error (dr)	Standardized Forecast Error (wr)
1961	27.26	27.55	-0.29	1.960	-0.148
1962	29.71	26.70	3.01	4.490	0.670
1963	25.71	25.98	-0.27	1.490	-0.181
1964	24.12	25.26	-1.14	2.151	-0.530
1965	26.44	28.84	-2.40	4.513	-0.532
1966	26.45	25.33	1.12	0.995	1.125
1967	25.29	26.55	-1.26	1.017	-1.239
1968	25.79	25.22	0.57	0.989	0.576
1969	26.82	25.40	1.42	0.701	2.026
1970	25.24	25.65	-0.41	0.707	-0.580
1971	26.70	27.89	-1.19	1.046	-1.138
1972	28.56	27.99	0.57	0.823	0.693
1973	33.46	36.79	-3.33	2.575	-1.293
1974	28.46	29.19	-0.83	0.638	-1.301
1975	27.67	27.02	0.65	1.093	0.595
1976	22.94	23.33	-0.39	0.825	-0.473
1977	22.25	27.29	-5.04	0.623	-8.090
1978	26.79	30.76	-3.97	0.705	-5.631
1979	31.16	37.78	-6.62	1.501	-4.410
1980	27.13	32.93	-5.80	0.920	-6.304
1981	23.43	30.01	-6.58	0.808	-8.144
1982	22.24	26.92	-4.68	0.767	-6.102
1983	20.95	25.97	-5.02	0.629	-7.981
1984	21.06	27.39	-6.33	0.686	-9.227
1985	18.07	24.02	-5.95	0.636	-9.355

parameters. The tendency to overpredict beef prices in the latter part of the sample is well pointed out by a run of 10 consecutive negative residuals from 1976 to 1985.

The contrast in the size of the recursive residuals is well underscored by the cumulative sum of squares residuals (CUSUMSQ) and the heteroscedasticity tests which are both significant at the 5 percent level (see Table 5.1). The plot of the CUSUMSQ (Figure 5.3) crosses the confidence boundary in 1967 and is outside the boundary until after 1983. Although the CUSUM is not statistically significant at the 5 percent level, the plot of the CUSUM series for beef (Figure 5.1) shows a systematic drift in the residuals starting sometime in 1977. This timing of discontinuity indicated by the recursive residuals is consistent with the timing of structural break indicated by the plot of the Quandt's log-likelihood ratio (Figure 5.4). The latter reaches a global minimum in 1976-1977.

Furthermore, the global location tests are all significant at the 5 percent level. This indicates that the expected value of the recursive residuals is not equal to zero, hence violating the required characteristics of the recursive residuals under the null hypothesis of constant parameters.

For k=1960-70 (see table 5.6), discontinuities in the size of the recursive residuals occurs in two years: 1976 and 1983. The average size of the residuals for the period

Table 5.6 Beef Inverse Demand Equation: Recursive Residual Analysis
k = 1960-1970, r = 1971, 1972,...,1985

Year	Actual Value $/cwt.	Recursive One-Step Ahead Forecast $/cwt.	Forecast Error $/cwt.	Variance of Forecast Error (dr)	Standardized Forecast Error (wr)
1971	26.70	27.88	-1.18	1.576	-0.746
1972	28.56	27.73	0.83	0.894	0.926
1973	33.46	36.75	-3.29	3.629	-0.904
1974	28.36	29.22	-0.86	0.644	-1.326
1975	27.67	27.44	0.23	1.325	0.180
1976	22.94	23.70	-0.76	1.042	-0.730
1977	22.25	27.42	-5.17	0.640	-8.073
1978	26.79	30.78	-3.99	0.771	-5.190
1979	31.16	36.59	-5.43	2.472	-2.197
1980	27.13	31.49	-4.36	1.044	-4.178
1981	23.43	27.89	-4.46	0.956	-4.665
1982	22.24	24.40	-2.16	0.883	-2.444
1983	20.95	24.61	-3.66	0.651	-5.620
1984	21.06	27.17	-6.11	0.689	-8.864
1985	18.07	22.88	-4.81	0.648	-7.421

Table 5.7 Beef Inverse Demand Equation: Recursive Residual Analysis
k = 1970-1980, r = 1981,.., 1985

Year	Actual Value $/cwt.	Recursive One-Step Ahead Forecast $/cwt.	Forecast Error $/cwt.	Variance of Forecast Error (dr)	Standardized Forecast Error (wr)
1981	23.43	28.18	-4.75	1.166	-4.072
1982	22.24	24.68	-2.44	1.174	-2.077
1983	20.95	23.58	-2.63	0.682	-3.848
1984	21.06	24.89	-3.83	0.898	-4.262
1985	18.07	19.63	-1.56	0.805	-1.933

Figure 5.1

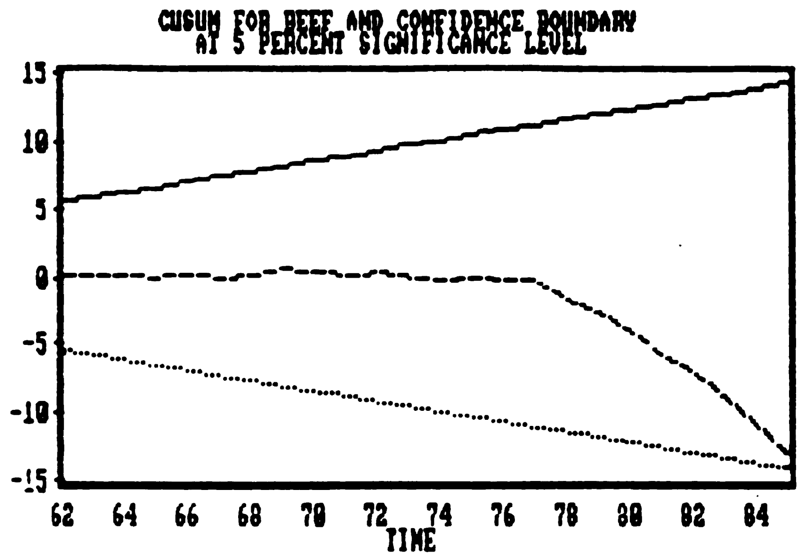


Figure 5.2

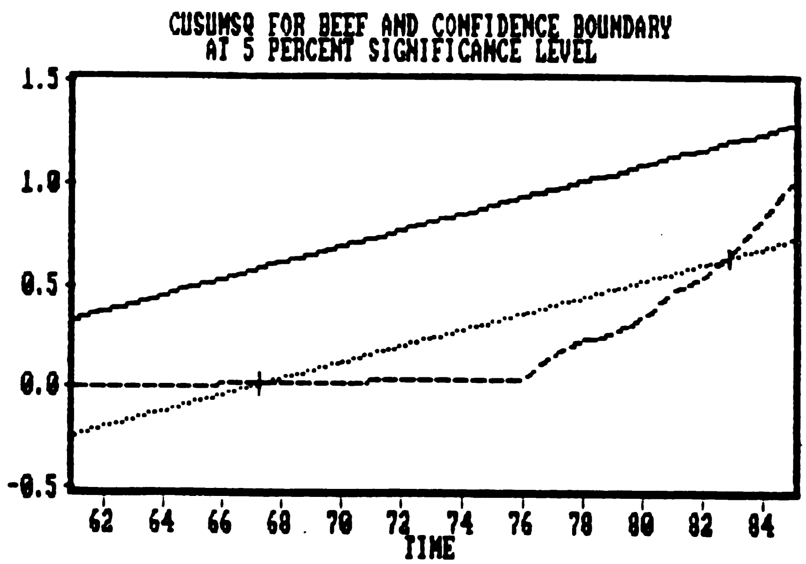


Figure 5.3

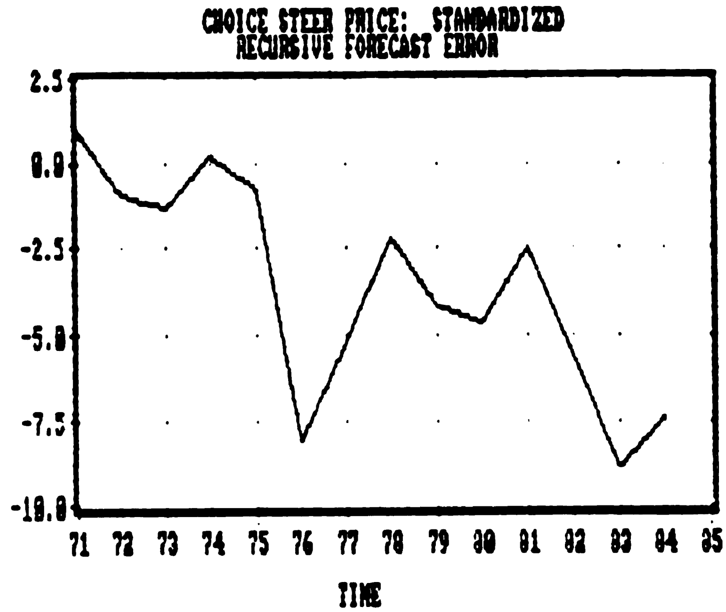
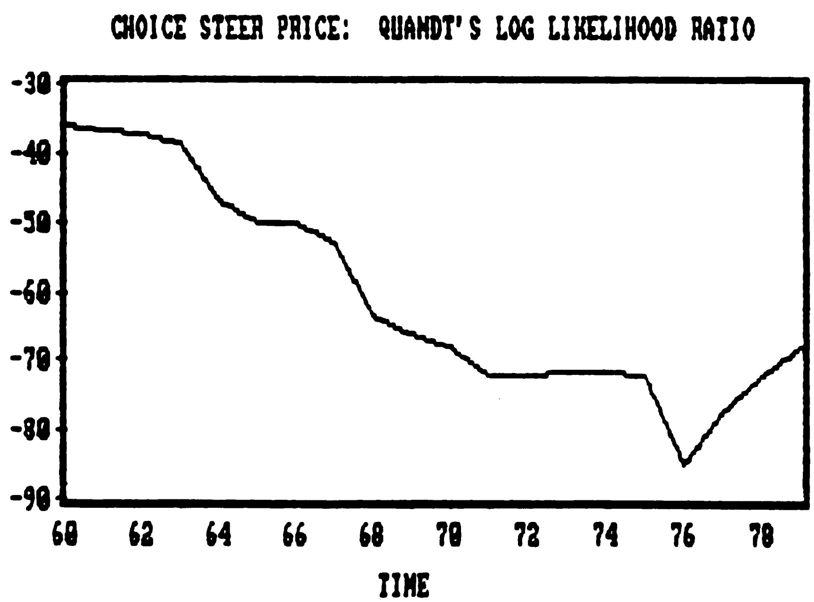


Figure 5.4



1960-77 through 1960-85 are more than twice as large in absolute value as the largest residual in the earlier part of the period (1960-70 through 1960-76). The recursive residuals indicate that the beef demand model tends to overpredict in the latter part of the sample.

The tendency to overpredict beef prices in the latter part of the period is underscored by a run of 10 consecutive negative residuals from 1977 to 1985.

Statistically, the contrast in the size of prediction errors is well pointed out by the CUSUMSQ and heteroscedasticity test (both significant at .05 level). The global location tests are significant at .05 level. This again underscores the contrasting behavior and size of predictions between the two subperiods.

The foregoing results strongly reject the hypothesis of constant parameters in the beef demand model. They suggest the presence of an important structural break and discontinuity sometime between mid and late 1970s and early 1980s.

5.1.2 Pork Demand

The recursive parameter estimates for the pork demand model are listed in Table 5.9 and plotted in Figures 5.5 to 5.8. The absolute value of the coefficient on pork per capita consumption (PKPC) exhibits an increasing trend from 1965 through 1971, except from 1968-70 where the coefficient slightly declined from -.6693 to -.6479 (see Figure 5.5).

A discontinuity beginning in 1971 is apparent, as the coefficient on PKPC started to decline in absolute value, from -.7167 in 1971 to -.5856 in 1978. After a slight increase from 1978 to 1980, the coefficient on PKPC trended downward starting in 1980. The corresponding own-quantity flexibility of demand for pork exhibited the same pattern as the coefficient on PKPC.

The coefficient for beef per capita consumption (see Figure 5.6) were relatively stable during the 1965 to 1970 period. Thereafter, it exhibited a declining trend, except from 1973 through 1977, when it slightly increased from 0.2916 to 0.3332.

The coefficient on poultry per capita consumption (see Figure 5.7) was relatively constant at around -0.3 during the period 1968 through 1976. A discontinuity is apparent in 1977 when the coefficient declined from -0.2510 in 1976 to -0.1707 in 1977. Starting from this point of discontinuity, the coefficient tended to trend upward, from -0.1707 in 1977 to -0.5254 in 1985.

The coefficient on real per capita disposable income (see figure 5.8) exhibits a downward trend starting in 1970. It declined from 0.0284 in 1970 to 0.0139 in 1985. The corresponding income flexibility of pork also exhibits a downward trend starting in the 1970s; however, it has not declined to near zero levels. This indicates that although

Table 5.8 Pork Inverse Demand Equation: Recursive Parameter Estimates, 1955-1985

Year	Constant	PKPC	BFPC	POULPC	DINC	R
1955-62	66.5140	-0.5750	-0.5410	-0.2370	0.0190	0.62
		(0.4280)	(0.4490)	(0.5040)	(0.0410)	
1955-63	48.3670	-0.5660	-0.4220	-0.3020	0.0240	0.62
		(0.4010)	(0.3910)	(0.4650)	(0.0380)	
1955-64	45.4120	-0.5890	-0.4320	-0.3380	0.0270	0.66
		(0.3210)	(0.3440)	(0.3280)	(0.0270)	
1955-65	46.0670	-0.5720	-0.4150	-0.3210	0.0250	0.73
		(0.2000)	(0.2370)	(0.2120)	(0.0120)	
1955-66	41.4810	-0.6150	-0.4550	-0.3600	0.0300	0.74
		(0.2070)	(0.2480)	(0.2220)	(0.0130)	
1955-67	43.1020	-0.6310	-0.4410	-0.3550	0.0290	0.74
		(0.1770)	(0.2210)	(0.2060)	(0.0100)	
1955-68	47.3050	-0.6690	-0.4060	-0.3080	0.0260	0.73
		(0.1610)	(0.2080)	(0.1870)	(0.0090)	
1955-69	44.7400	-0.6530	-0.4290	-0.3260	0.0280	0.72
		(0.1590)	(0.2050)	(0.1850)	(0.0090)	
1955-70	44.3310	-0.6480	-0.4310	-0.3230	0.0280	0.72
		(0.1470)	(0.1950)	(0.1750)	(0.0080)	
1955-71	48.2530	-0.7171	-0.3640	-0.3180	0.0260	0.75
		(0.1230)	(0.1780)	(0.1730)	(0.0080)	
1955-72	48.3160	-0.7120	-0.3430	-0.3110	0.0250	0.75
		(0.1180)	(0.1550)	(0.1650)	(0.0070)	
1955-73	47.6860	-0.6950	-0.2920	-0.2860	0.0220	0.87
		(0.1080)	(0.0960)	(0.1500)	(0.0030)	
1955-74	47.8340	-0.6950	-0.2890	-0.2820	0.0220	0.88
		(0.1040)	(0.0920)	(0.1440)	(0.0030)	
1955-75	45.8810	-0.6300	-0.3140	-0.2480	0.0210	0.91
		(0.0790)	(0.0880)	(0.1390)	(0.0030)	
1955-76	45.6000	-0.6150	-0.3290	-0.2510	0.0220	0.91
		(0.0690)	(0.0790)	(0.1350)	(0.0030)	
1955-77	46.1100	-0.5860	-0.3330	-0.1710	0.0190	0.86
		(0.0850)	(0.0980)	(0.1650)	(0.0030)	
1955-78	45.0280	-0.5690	-0.2500	-0.2000	0.0170	0.82
		(0.0930)	(0.1000)	(0.1810)	(0.0040)	
1955-79	44.6110	-0.6040	-0.1220	-0.3450	0.0150	0.80
		(0.0960)	(0.0710)	(0.1700)	(0.0040)	
1955-80	44.7580	-0.6100	-0.1150	-0.3580	0.0150	0.81
		(0.0910)	(0.0640)	(0.1570)	(0.0040)	
1955-81	44.0000	-0.6040	-0.1010	-0.4120	0.0160	0.81
		(0.0900)	(0.0610)	(0.1410)	(0.0030)	
1955-82	42.2910	-0.5790	-0.0930	-0.4650	0.0160	0.81
		(0.0850)	(0.0600)	(0.1260)	(0.0030)	
1955-83	41.7680	-0.5730	-0.0820	-0.5040	0.0170	0.80
		(0.0860)	(0.0610)	(0.1240)	(0.0030)	
1955-84	39.8710	-0.5510	-0.0180	-0.4880	0.0140	0.75
		(0.0970)	(0.0640)	(0.1410)	(0.0040)	
1955-85	38.6750	-0.5340	-0.0060	-0.5250	0.0140	0.70
		(0.1020)	(0.0660)	(0.1470)	(0.0040)	

Numbers in parenthesis are standard errors

Figure 5.5

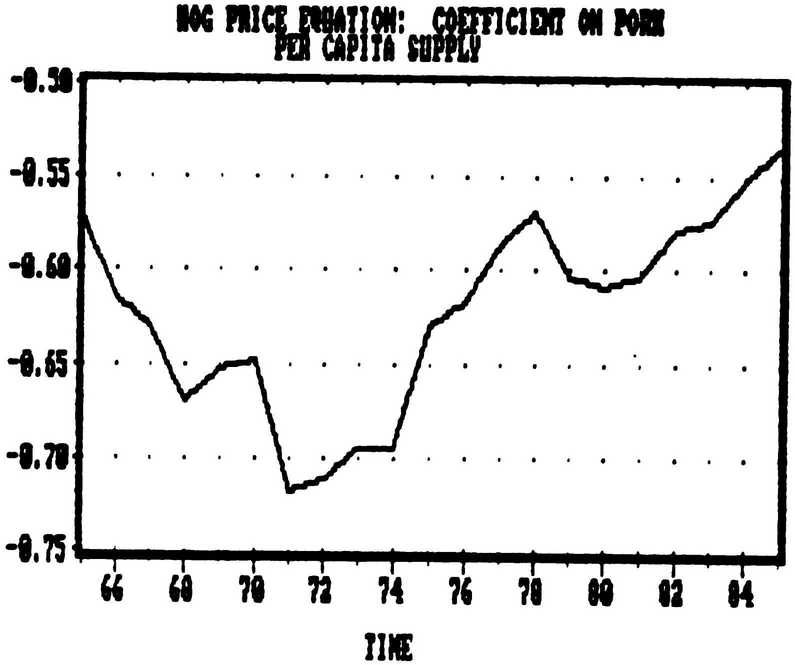


Figure 5.6

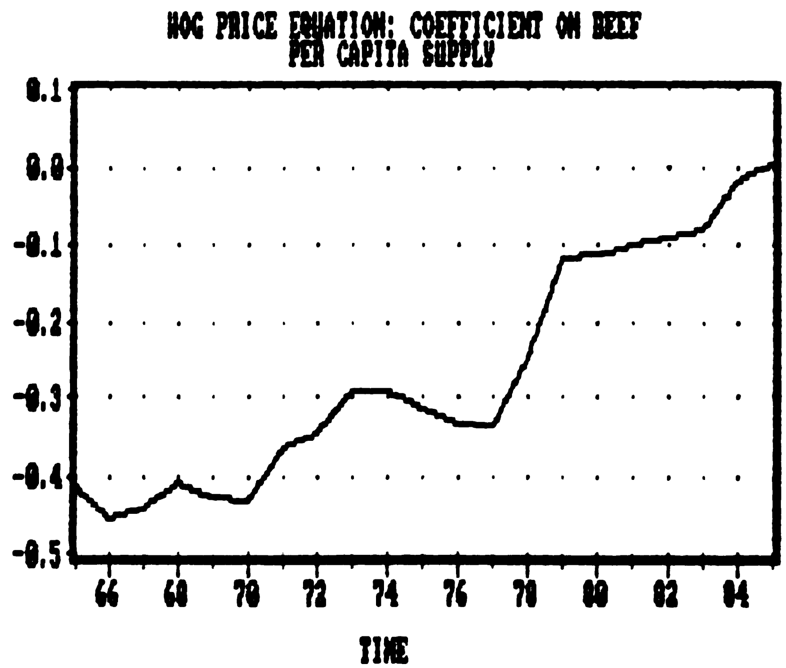


Figure 5.7

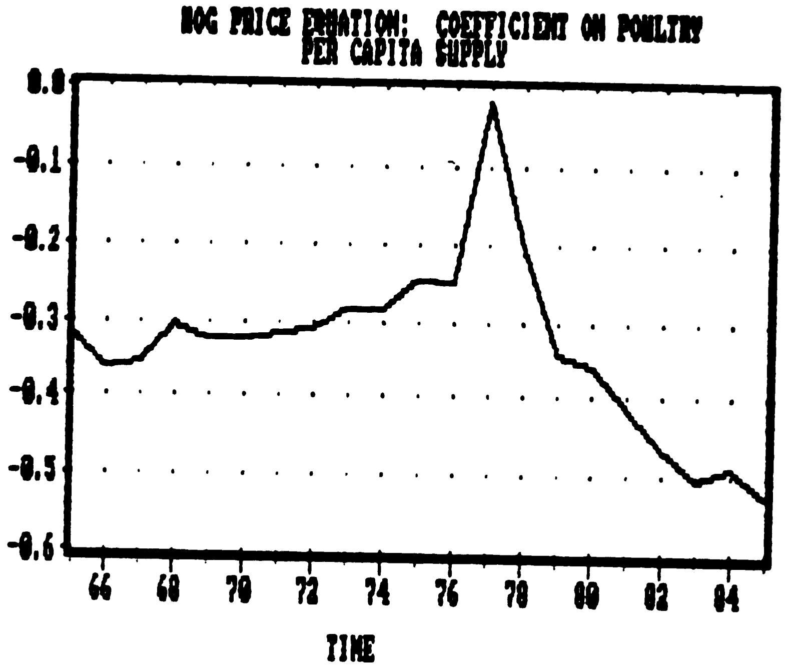
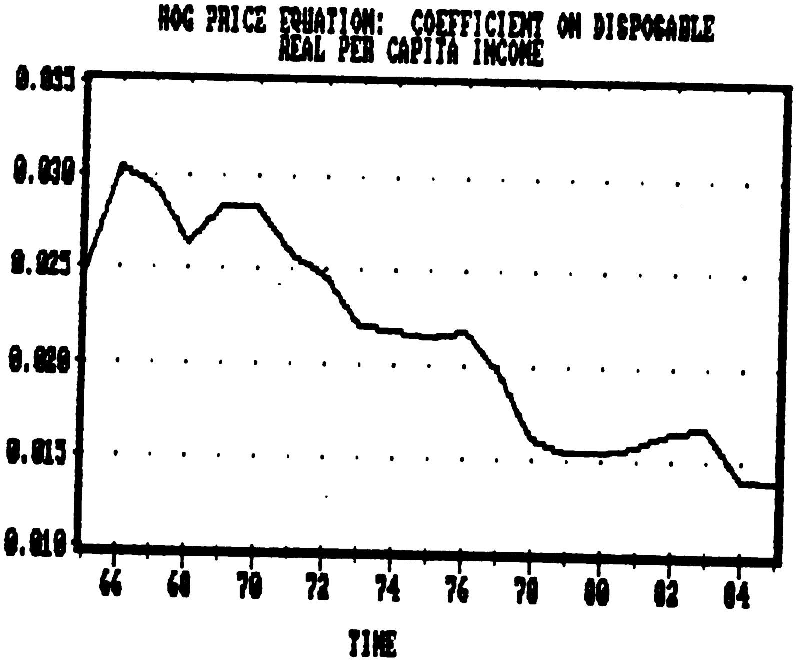


Figure 5.8



the price response to income changes might be weakening starting in the 1970s, income is still a significant factor in determining the future demand for red meat and, hence, the future growth of the meat sector. These results indicate that pork price is about 40 percent less responsive in 1980 than in 1970 (i.e., decline in the income flexibility of pork from 3.5 in 1970 to around 2.0 in 1980).

The recursive residuals for the pork demand model are listed in Table 5.10 and plotted in Figure 5.11. The plot of the recursive residuals shows two periods with quite different patterns: 1965 to 1976 and 1977 to 1985. They differ in two ways. First, the average size of the residuals is much bigger in the second period than in the first period. Second, from the forward one step recursive residuals, there is a tendency to overpredict starting in 1971, reaching the two largest overpredictions in 1977 and 1984. From 1965 to 1971, the recursive residuals tend to fluctuate. A discontinuity is apparent in 1977 when the residuals jumped from -0.921 in 1976 to -7.833 in 1977. Four among nine residuals during the period 1977 to 1985 are nearly twice as large in absolute value as the largest residual prior to 1977.

The CUSUM plot for pork (see Figure 5.9) indicate a systematic drift in the recursive residuals starting sometime in 1976. The CUSUMSQ plot indicate discontinuity in the parameters sometime in the mid 1970s and between

Table 5.9 Pork Inverse Demand Equation: Recursive Residual Analysis
k = 1955-1960, r = 1961, 1962,...1985

Year	Actual Value $/cwt.	Recursive One-Step Ahead Forecast $/cwt.	Forecast Error $/cwt.	Variance of Forecast Error (dr)	Standardized Forecast Error (wr)
1961	19.15	12.55	6.60	1.960	3.360
1962	18.56	13.29	5.27	4.490	1.170
1963	16.77	14.03	2.74	1.490	1.840
1964	16.48	15.93	0.55	2.151	0.260
1965	22.55	22.97	-0.42	4.153	-0.093
1966	24.17	21.00	3.17	0.995	3.186
1967	19.37	19.83	-0.46	1.017	-0.452
1968	18.42	19.95	-1.53	0.989	-1.547
1969	21.59	19.82	1.77	0.701	2.525
1970	18.87	18.62	0.25	0.707	0.354
1971	15.21	17.17	-1.96	1.046	-1.874
1972	21.28	21.81	-0.53	0.823	-0.644
1973	30.26	31.67	-1.41	2.575	-0.548
1974	23.78	24.13	-0.35	0.638	-0.549
1975	29.98	31.90	-1.92	1.093	-1.757
1976	25.28	26.04	-0.76	0.825	-0.921
1977	22.63	27.51	-4.88	0.623	-7.833
1978	24.82	29.21	-4.39	0.705	-6.227
1979	19.54	25.06	-5.52	1.501	-3.678
1980	16.22	16.87	-0.65	0.920	-0.706
1981	16.32	18.23	-1.91	0.808	-2.364
1982	19.18	21.14	-1.96	0.767	-2.555
1983	15.98	18.74	-2.76	0.629	-4.388
1984	15.71	21.97	-6.26	0.686	-9.125
1985	13.86	18.51	-4.65	0.636	-7.311

Figure 5.9

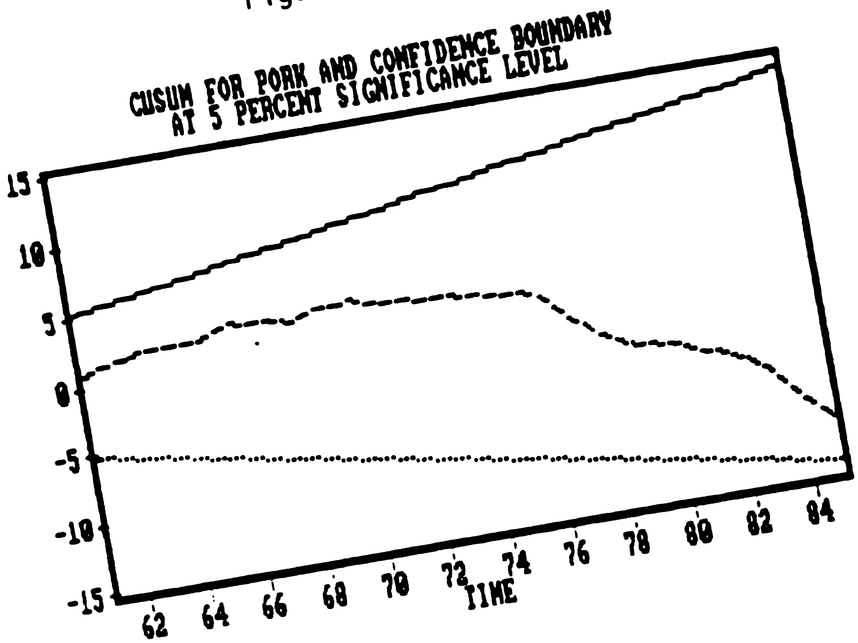


Figure 5.10

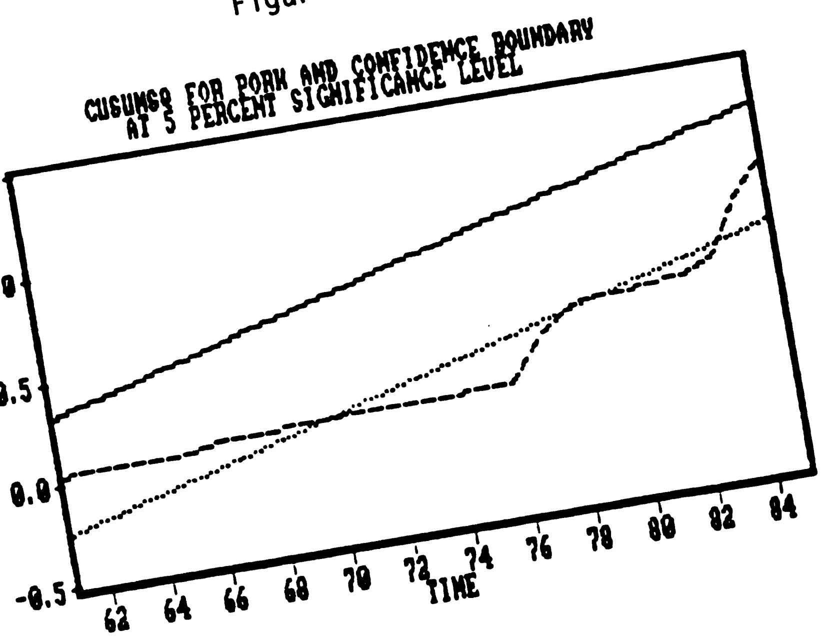


Figure 5.11

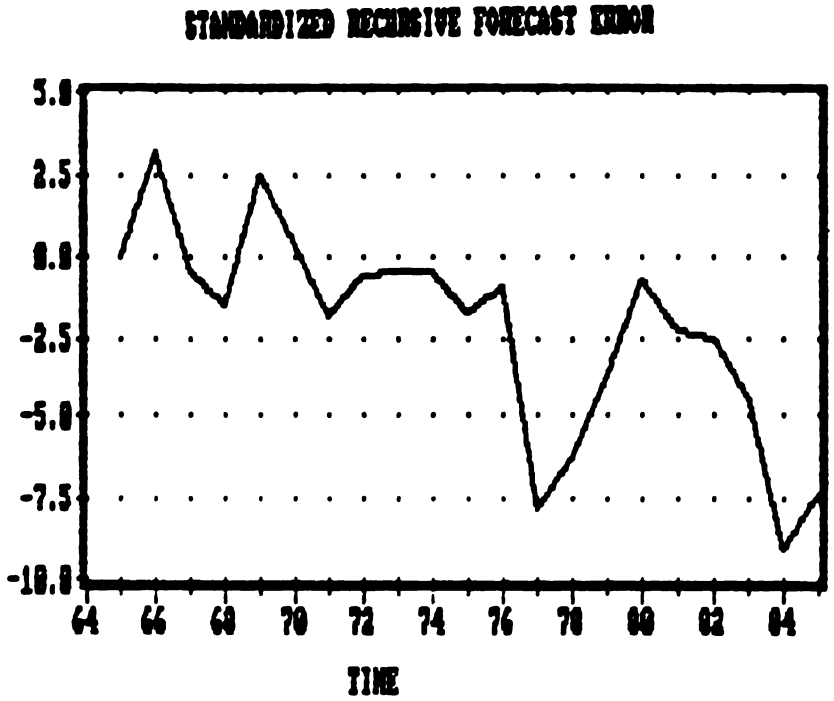
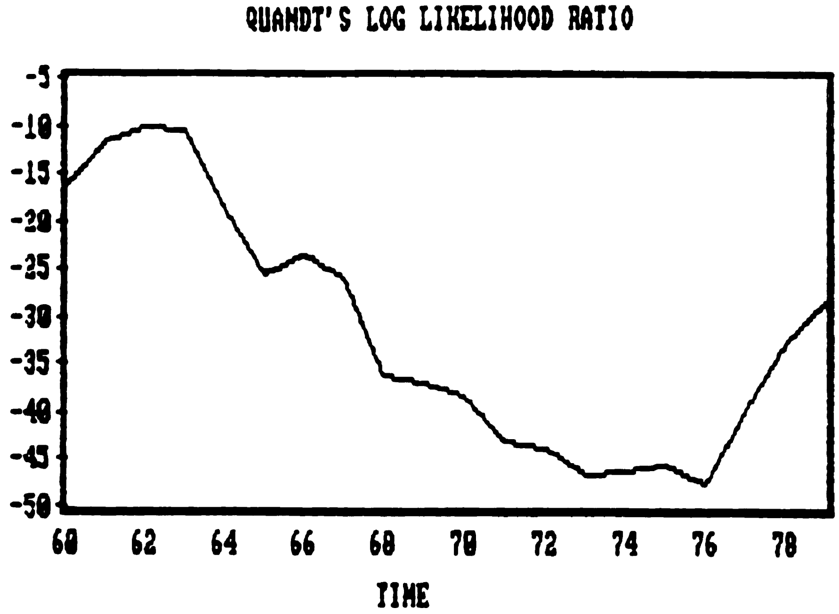


Figure 5.12



1980-1983. The discontinuity in the parameters starting sometime in mid 1970s is confirmed by the plot of the Quandt's log likelihood ratio where a global minimum is reached sometime in 1976. The cumulative sum of squares statistic and the heteroscedasticity tests are both significant at the .05 level (see Table 5.1).

The tendency to overpredict is indicated in a simple way by observing a run of 15 consecutive negative one step residuals from 1971 to 1985. The probability under the null hypothesis of obtaining at least one run of this length or greater is .00028. The global location tests are significant at level .05, indicating the rejection of hypothesis of zero mean of the residuals.

These results strongly reject the null hypothesis of constant parameters in the pork inverse demand model. The results suggest the presence of an important structural break in the demand for pork starting around 1976-1977.

5.1.3 Demand for Broilers

The recursive estimates for the broiler demand model are listed in Table 5.11 and plotted in Figure 5.13- 5.17. The coefficient on per capita broiler consumption exhibits three different patterns. During the first five periods, the coefficient slightly increased (in absolute value) from -1.3241 in 1964 to -1.6512 in 1968. It then declined to

Table 5.10 Broiler Inverse Demand Equation: Recursive Parameter Estimates, 1955-1985

Year	Constant	CHPC	TKPC	BFPC	PKPC	DINC	R
1955-62	62.075	-1.515	-0.322	-0.238	-0.075	0.013	0.95
		(0.993)	(2.383)	(0.647)	(0.397)	(0.046)	
1955-63	54.317	-1.300	-0.996	-0.043	-0.037	0.007	0.96
		(0.756)	(1.628)	(0.423)	(0.334)	(0.038)	
1955-64	53.057	-1.324	-0.983	-0.051	-0.047	0.008	0.96
		(0.553)	(1.398)	(0.346)	(0.253)	(0.025)	
1955-65	49.639	-1.463	-0.849	-0.148	-0.120	0.017	0.96
		(0.392)	(1.238)	(0.224)	(0.160)	(0.012)	
1955-66	43.910	-1.569	-0.676	-0.216	-0.163	0.024	0.94
		(0.470)	(1.492)	(0.268)	(0.192)	(0.013)	
1955-67	42.713	-1.609	-0.553	-0.237	-0.150	0.026	0.95
		(0.354)	(1.129)	(0.209)	(0.157)	(0.010)	
1955-68	46.822	-1.651	-0.212	-0.228	-0.185	0.024	0.95
		(0.337)	(0.977)	(0.202)	(0.143)	(0.009)	
1955-69	44.754	-1.488	-0.816	-0.197	-0.178	0.023	0.94
		(0.308)	(0.827)	(0.203)	(0.145)	(0.009)	
1955-70	42.300	-1.336	-1.195	-0.171	-0.145	0.021	0.94
		(0.292)	(0.793)	(0.208)	(0.147)	(0.010)	
1955-71	41.885	-1.338	-1.190	-0.179	-0.138	0.022	0.95
		(0.277)	(0.754)	(0.183)	(0.119)	(0.009)	
1955-72	41.970	-1.329	-1.203	-0.166	-0.136	0.021	0.95
		(0.260)	(0.717)	(0.157)	(0.114)	(0.007)	
1955-73	41.995	-1.335	-1.194	-0.172	-0.137	0.021	0.95
		(0.219)	(0.663)	(0.090)	(0.106)	(0.003)	
1955-74	41.988	-1.335	-1.194	-0.172	-0.137	0.021	0.95
		(0.210)	(0.639)	(0.086)	(0.102)	(0.003)	
1955-75	40.529	-1.350	-1.053	-0.188	-0.097	0.021	0.93
		(0.204)	(0.577)	(0.080)	(0.072)	(0.003)	
1955-76	42.423	-1.276	-1.243	-0.111	-0.174	0.019	0.92
		(0.228)	(0.649)	(0.083)	(0.073)	(0.003)	
1955-77	42.883	-1.212	-1.279	-0.113	-0.160	0.018	0.92
		(0.236)	(0.680)	(0.087)	(0.076)	(0.003)	
1955-78	42.857	-1.213	-1.277	-0.112	-0.159	0.018	0.91
		(0.228)	(0.659)	(0.078)	(0.074)	(0.003)	
1955-79	43.422	-1.058	-1.223	-0.229	-0.128	0.019	0.90
		(0.233)	(0.713)	(0.058)	(0.078)	(0.003)	
1955-80	42.520	-0.983	-1.125	-0.271	-0.095	0.019	0.89
		(0.242)	(0.749)	(0.056)	(0.080)	(0.003)	
1955-81	43.882	-0.883	-1.061	-0.294	-0.105	0.018	0.90
		(0.242)	(0.775)	(0.056)	(0.083)	(0.003)	
1955-82	44.889	-0.835	-1.120	-0.297	-0.118	0.018	0.90
		(0.214)	(0.751)	(0.055)	(0.076)	(0.003)	
1955-83	45.141	-0.817	-1.095	-0.302	-0.121	0.018	0.91
		(0.211)	(0.743)	(0.054)	(0.076)	(0.003)	
1955-84	45.083	-0.807	-1.132	-0.297	-0.119	0.018	0.90
		(0.201)	(0.707)	(0.049)	(0.074)	(0.003)	
1955-85	45.160	-0.828	-0.997	-0.304	-0.123	0.018	0.90
		(0.196)	(0.671)	(0.047)	(0.073)	(0.003)	

Numbers in parenthesis are standard errors

-1.3359 in 1970, then stayed relatively constant at around -1.3 during the six-year period, 1970 to 1975. Starting in 1975, the coefficient exhibits a systematic gradual downward trend from -1.3498 in 1975 to -.8279 in 1975.

The coefficient on per capita turkey consumption (Figure 5.14) first declined from -0.983 in 1964 to -0.2125 in 1968. A discontinuity is apparent between 1968 and 1970 when the coefficient sharply increased at -1.1951 in 1970 and stayed relatively constant at that level until 1974. The coefficient exhibits slight fluctuations from 1975 to 1985.

The coefficient on beef per capita consumption (see Figure 5.15) show a number of distinct patterns. A slight increase from -0.1485 in 1965 to -0.2371 in 1967 is shown after which the coefficient began to decline to -0.1712 in 1970 and stayed relatively constant around that level until 1974. Another discontinuity is apparent between 1975 and 1976 when the coefficient declined to -0.111. It stayed around that level until 1978 when a third discontinuity is observed. The coefficient exhibited a systematic increasing trend from 1978 through 1983, and then stayed relatively constant at around -0.3 during the last three years.

The coefficient on pork per capita consumption (see Figure 5.16) first increased in absolute value from -0.1197 to -0.1848 in 1968 and then declined to about -0.14 in 1970. It then stayed relatively constant at that level through

Figure 5.13

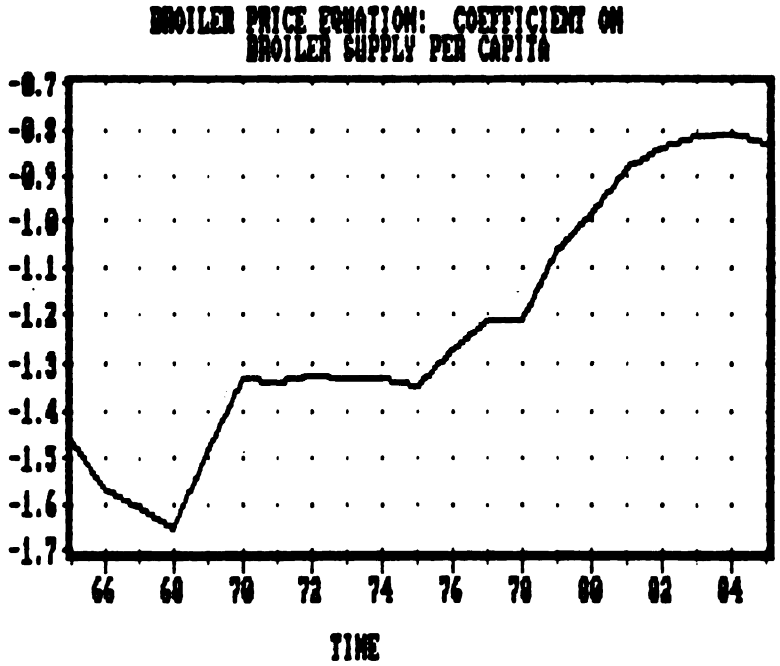


Figure 5.14

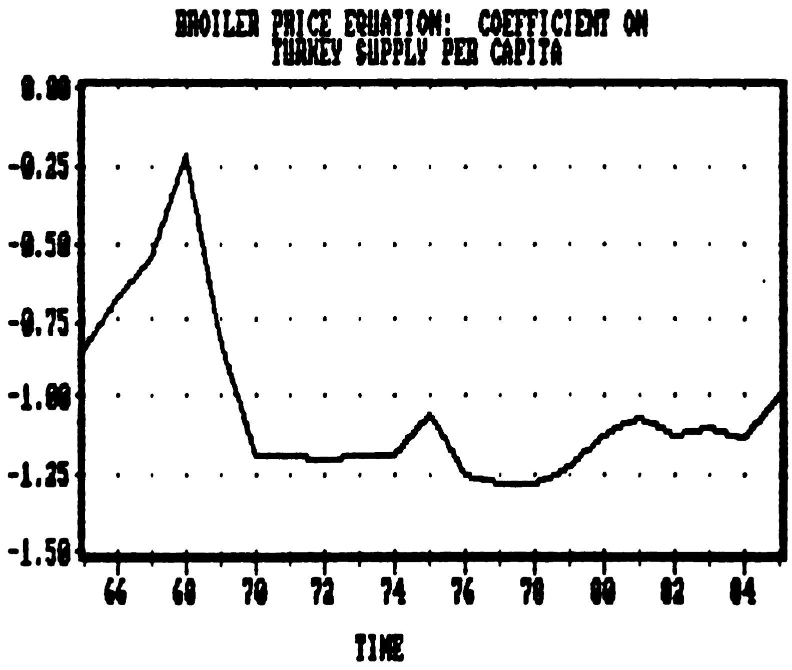


Figure 5.15

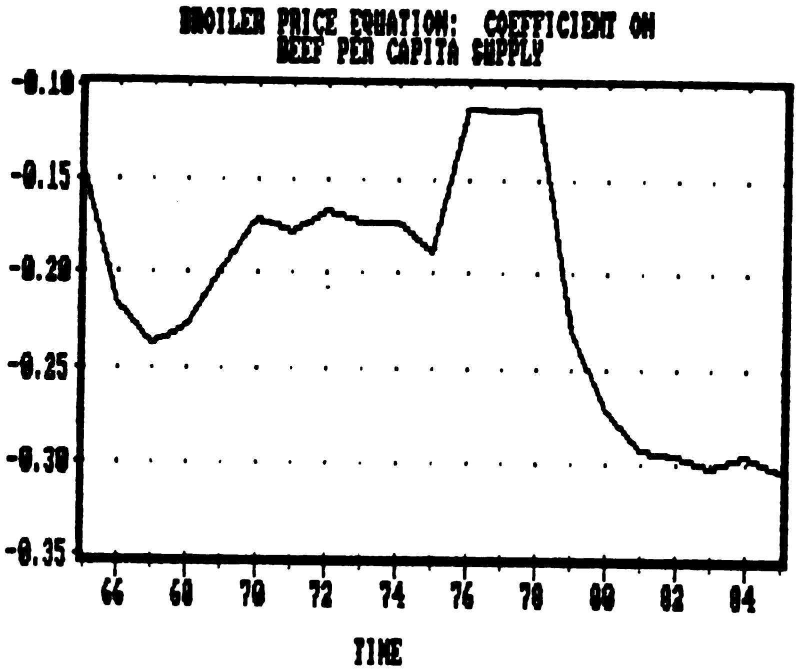


Figure 5.16

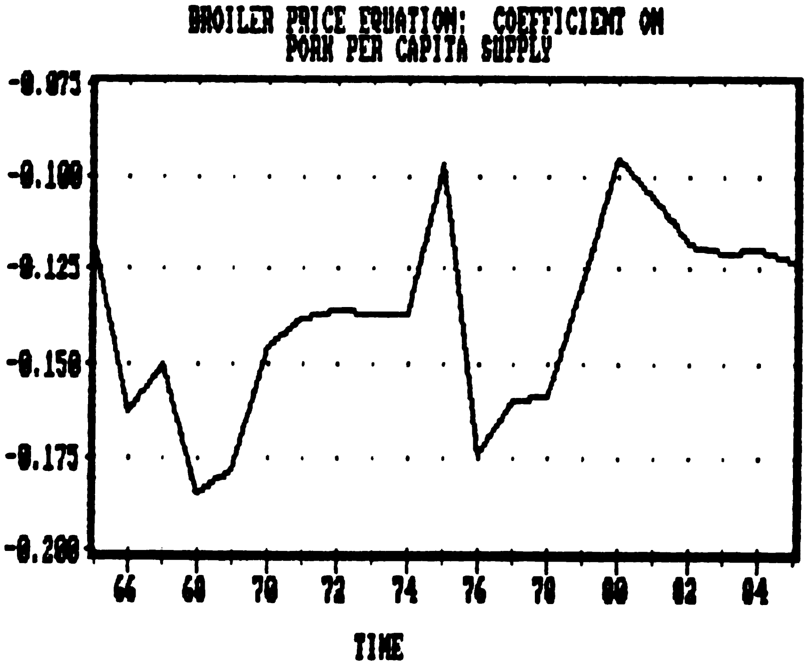


Figure 5.17

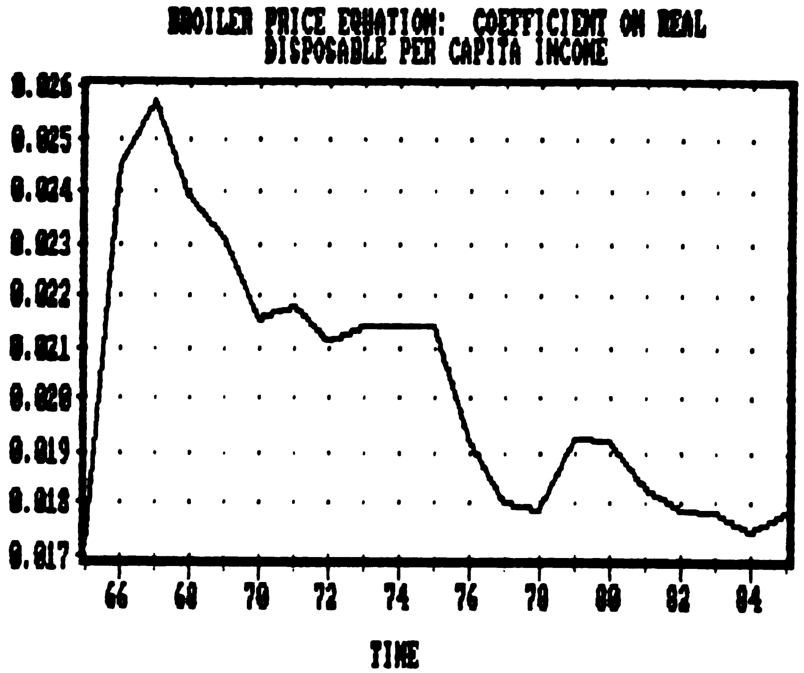
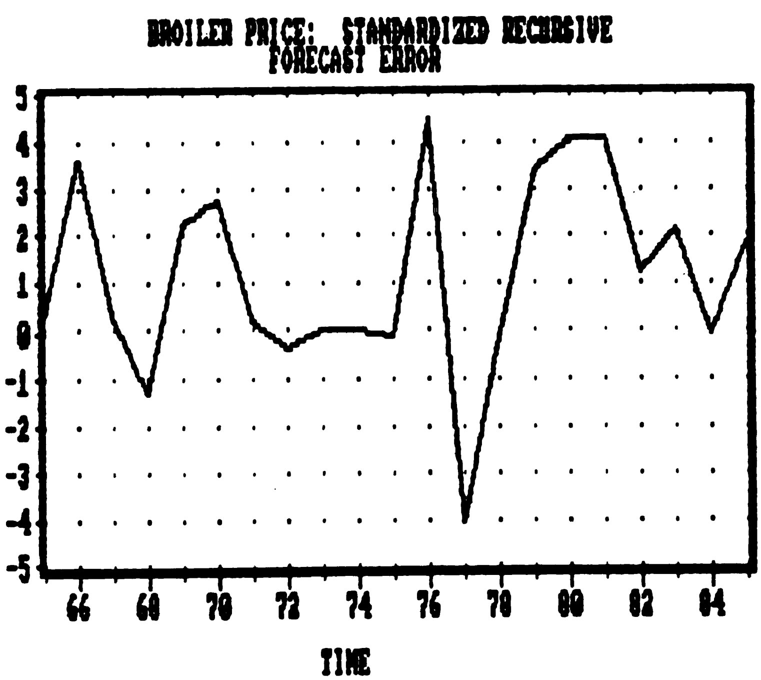


Figure 5.18



1974. A decline to -0.0968 in 1975 is shown and then an increase to -0.1743 in 1976. The coefficient then declined starting in 1977 through 1980, after which it slightly increased from -0.1054 in 1981 to -0.1231 in 1985.

The coefficient on real per capita disposable income (see Figure 5.17) first slightly increased from 0.0172 in 1965 to 0.0257 in 1967. A slight decline to 0.0211 in 1972 from the 1967 level is shown. The coefficient then stayed at a relatively constant level of 0.0214 during the next three years (1973 to 1975), after which a slight decline occured in 1985 reaching a level of 0.0178.

The recursive residuals for the broiler demand model are listed in Table 5.12 and plotted in Figure 5.18.
The residuals during the early 1970s, say 1971 to mid 70s were small and relatively constant near zero. A discontinuity occured starting in 1976 when the residuals become larger in absolute value. The model underpredicted in 1975 and overpredicted in 1977 and 1978. A run of underpredictions occurs during 1979 through 1983 and in 1985.

The CUSUMSQ series for broilers crossed the confidence boundary sometime in the mid 1970s, indicating a discontinuity in the demand parameters around that period (Figure 5.20). The plot of the Quandt's log likelihoold ratio (see Figure 5.21) has a global minimum in 1975. The location and serial dependence tests are significant at .05

Table 5.11 Broiler Inverse Demand Equation: Recursive Residual Analysis
k = 1955-1961, r = 1962, 1963,..., 1985

Year	Actual Value (cents.lb)	Recursive One-Step Ahead Forecast (cents/lb)	Forecast Error (cents.lb)	Variance of Forecast Error (dr)	Standardized Forecast Error (wr)
1962	16.78	8.49	8.29	7.055	1.18
1963	15.92	13.99	1.93	2.286	0.84
1964	15.28	15.07	0.21	2.329	0.09
1965	15.87	14.01	1.86	5.212	0.36
1966	15.74	12.11	3.63	1.003	3.62
1967	13.30	12.90	0.40	1.578	0.26
1968	13.63	15.16	-1.53	1.176	-1.31
1969	13.84	11.58	2.26	0.995	2.27
1970	11.69	9.33	2.36	0.839	2.82
1971	11.38	11.18	0.20	1.053	0.19
1972	11.25	11.53	-0.28	0.822	-0.34
1973	18.03	17.88	0.15	2.934	0.05
1974	14.55	14.54	0.01	0.639	0.02
1975	16.32	17.46	-1.14	1.240	-0.92
1976	13.55	9.74	3.81	0.846	4.50
1977	12.95	15.51	-2.56	0.626	-4.09
1978	13.51	13.59	-0.08	0.710	-0.11
1979	11.96	6.85	5.11	1.507	3.39
1980	11.26	7.49	3.77	0.920	4.10
1981	10.28	7.00	3.28	0.808	4.06
1982	9.30	8.31	0.99	0.813	1.23
1983	9.79	8.41	1.38	0.629	2.19
1984	10.76	11.18	-0.42	0.730	-0.57
1985	9.32	8.04	1.28	0.684	1.86

Figure 5.19

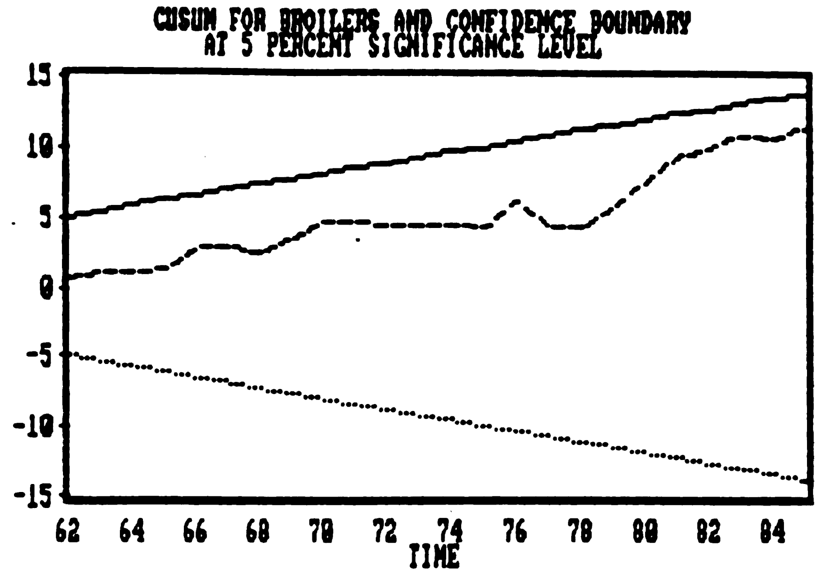
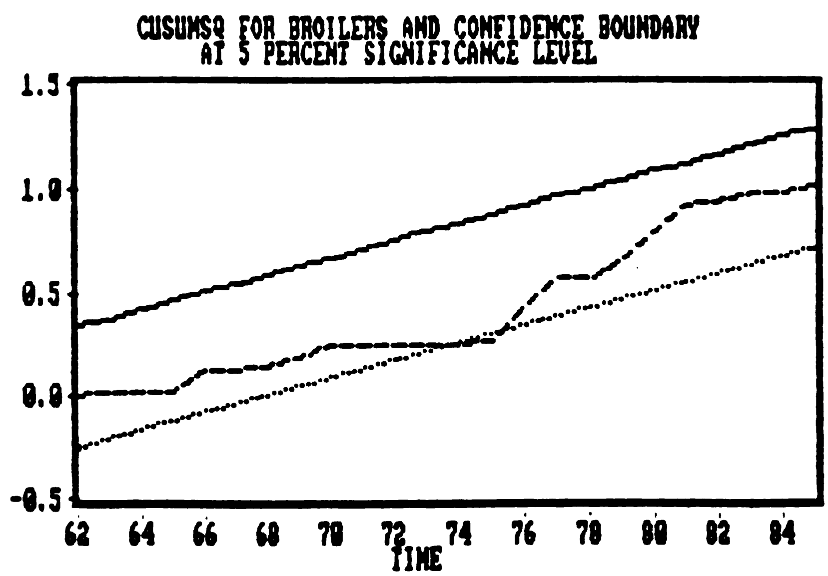


Figure 5.20



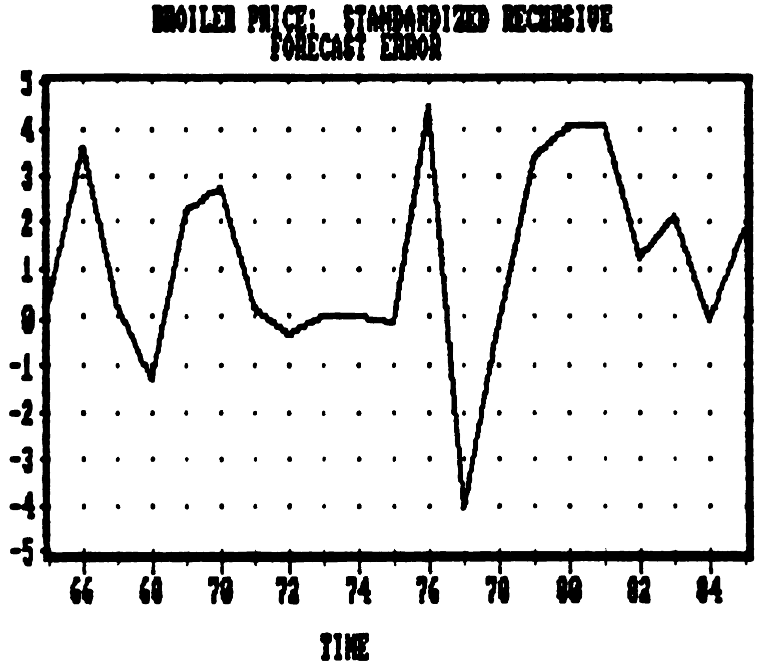
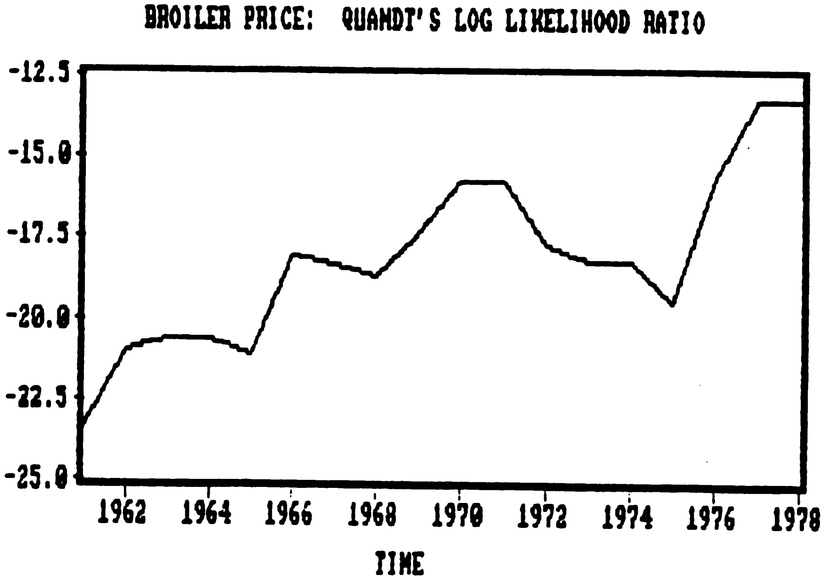

BROILER PRICE: STANDARDIZED RECURSIVE FORECAST ERROR
5
4
3
2
1
0
-1
-2
-3
-4
-5
66
68
70
72
74
76
78
80
82
84
TIME

Figure 5.21


BROILER PRICE: QUANDT'S LOG LIKELIHOOD RATIO
-12.5
-15.0
-17.5
-20.0
-22.5
-25.0
1962
1964
1966
1968
1970
1972
1974
1976
1978
TIME

level indicating rejection of the hypothesis that the $E(w_r)$ $= 0$ and $E(w_r w_s) = 0$. This means that the characteristics of the recursive residuals under the null hypothesis of parameter stability are rejected. The discontinuity in the size of the residuals near 1976 is pointed out by the heteroscedasticity tests which is significant at level .05.

The foregoing results strongly reject the null hypothesis of constant parameters in the broiler inverse demand model. The results indicate a structural shift sometime in the mid 1970s.

5.1.4 Demand for Turkey

Recursive estimates for the turkey demand model are listed in Table 5.13 and plotted in Figure 5.22 - 5.26. The coefficient on per capita turkey consumption (see Figure 5.22) averaged around -1.7621 from the period 1955-70 through 1955-72 and then declined slightly to about -1.38 in 1973 and 1974. The coefficient further declined to about -1.06 in 1975 and then increased slightly in 1976 to -1.276. Starting in 1976, the coefficient is relatively constant at about -1.3 until in 1985 when it slightly declined to -1.1356.

The recursive coefficient on broiler per capita consumption (see Figure 5.23) showed some fluctuations during the period 1955-66 through 1955-69, averaging around

-1.2238. The coefficient during the period 1970 to 1972 stayed relatively constant at around -1.076, a slight lower average than the preceding four years. A discontinuity is evident in 1973 when the coefficient increased in absolute value to -1.3206 and stayed at around -1.3 through 1975. Starting in 1976, the coefficient on broiler per capita consumption systematically declined and then leveled off at around -1.1 starting in 1979 through the rest of the period.

The recursive estimates of the coefficients on per capita beef consumption (see Figure 5.24) exhibited a downward trend (in absolute values) from 1955-1966 through 1955-1972 period. A discontinuity occurs in 1973 when the coefficient increased in absolute value at around -0.3424 and stayed relatively constant at about -0.33 during the rest of the period, except in 1976 and 1977 when the coefficient slightly declined to about -0.27.

The recursive coefficients on per capita pork consumption exhibits a relatively small variation (Figure 5.25). A slight upward trend (in absolute values) occurs from 1970 through 1974. Except during 1975, the coefficients were relatively constant during the late 1970s through the 1980s.

The recursive coefficients on real per capita disposable income exhibited a downward trend from 1966 through 1972 (Figure 5.26). A discontinuity occurs in 1973 when the income coefficient increased to 0.0275 from 0.0143 in 1972. The coefficient slightly declined from the 1973 level

Table 5.12 Turkey Inverse Demand Equation: Recursive Parameter Estimates, 1955-1985

Year	Constant	TKPC	CHPC	BFPC	PKPC	DINC	R
1955-62	55.533	-3.071	-0.294	0.358	0.611	0.031	0.98
		(1.661)	(0.692)	(0.451)	(0.277)	(0.032)	
1955-63	58.559	-2.809	-0.378	0.282	0.597	0.028	0.98
		(1.096)	(0.509)	(0.285)	(0.225)	(0.026)	
1955-64	50.738	-2.731	-0.525	0.232	0.537	0.019	0.98
		(0.986)	(0.390)	(0.244)	(0.178)	(0.018)	
1955-65	34.765	-2.106	-1.173	-0.222	0.198	0.021	0.95
		(1.419)	(0.450)	(0.258)	(0.184)	(0.014)	
1955-66	27.971	-1.901	-1.300	-0.303	0.147	0.030	0.92
		(1.736)	(0.546)	(0.312)	(0.223)	(0.016)	
1955-67	33.937	-2.516	-1.105	-0.200	0.083	0.024	0.93
		(1.353)	(0.424)	(0.251)	(0.188)	(0.012)	
1955-68	48.951	-1.270	-1.262	-0.166	-0.044	0.018	0.89
		(1.439)	(0.496)	(0.298)	(0.212)	(0.014)	
1955-69	45.570	-1.381	-1.231	-0.160	-0.043	0.018	0.90
		(1.134)	(0.423)	(0.279)	(0.199)	(0.013)	
1955-70	46.257	-1.739	-1.087	-0.136	-0.012	0.016	0.90
		(1.043)	(0.384)	(0.273)	(0.194)	(0.013)	
1955-71	48.508	-1.768	-1.074	-0.096	-0.051	0.015	0.91
		(0.998)	(0.367)	(0.242)	(0.158)	(0.012)	
1955-72	48.573	-1.779	-1.068	-0.087	-0.049	0.014	0.92
		(0.950)	(0.344)	(0.208)	(0.150)	(0.010)	
1955-73	49.704	-1.384	-1.321	-0.342	-0.102	0.027	0.91
		(0.961)	(0.318)	(0.131)	(0.154)	(0.005)	
1955-74	51.514	-1.385	-1.258	-0.313	-0.106	0.025	0.89
		(1.034)	(0.340)	(0.139)	(0.165)	(0.005)	
1955-75	48.110	-1.056	-1.291	-0.350	-0.012	0.025	0.88
		(0.944)	(0.333)	(0.131)	(0.118)	(0.005)	
1955-76	50.010	-1.246	-1.218	-0.273	-0.089	0.022	0.87
		(0.967)	(0.341)	(0.124)	(0.109)	(0.005)	
1955-77	50.402	-1.277	-1.162	-0.275	-0.076	0.021	0.87
		(0.964)	(0.335)	(0.123)	(0.108)	(0.005)	
1955-78	50.797	-1.309	-1.143	-0.298	-0.081	0.022	0.87
		(0.941)	(0.325)	(0.112)	(0.105)	(0.004)	
1955-79	50.949	-1.294	-1.101	-0.330	-0.073	0.022	0.87
		(0.919)	(0.300)	(0.075)	(0.101)	(0.004)	
1955-80	50.953	-1.294	-1.101	-0.330	-0.073	0.022	0.88
		(0.894)	(0.288)	(0.067)	(0.095)	(0.004)	
1955-81	51.170	-1.284	-1.085	-0.334	-0.075	0.022	0.89
		(0.872)	(0.272)	(0.063)	(0.093)	(0.004)	
1955-82	51.323	-1.293	-1.078	-0.334	-0.077	0.022	0.90
		(0.840)	(0.240)	(0.062)	(0.086)	(0.004)	
1955-83	51.063	-1.320	-1.100	-0.329	-0.074	0.022	0.92
		(0.829)	(0.235)	(0.060)	(0.084)	(0.004)	
1955-84	50.917	-1.412	-1.071	-0.317	-0.071	0.022	0.92
		(0.793)	(0.225)	(0.054)	(0.083)	(0.003)	
1955-85	51.794	-1.136	-1.114	-0.331	-0.078	0.022	0.91
		(0.769)	(0.225)	(0.054)	(0.083)	(0.003)	

Numbers in parenthesis are standard errors

Figure 5.22

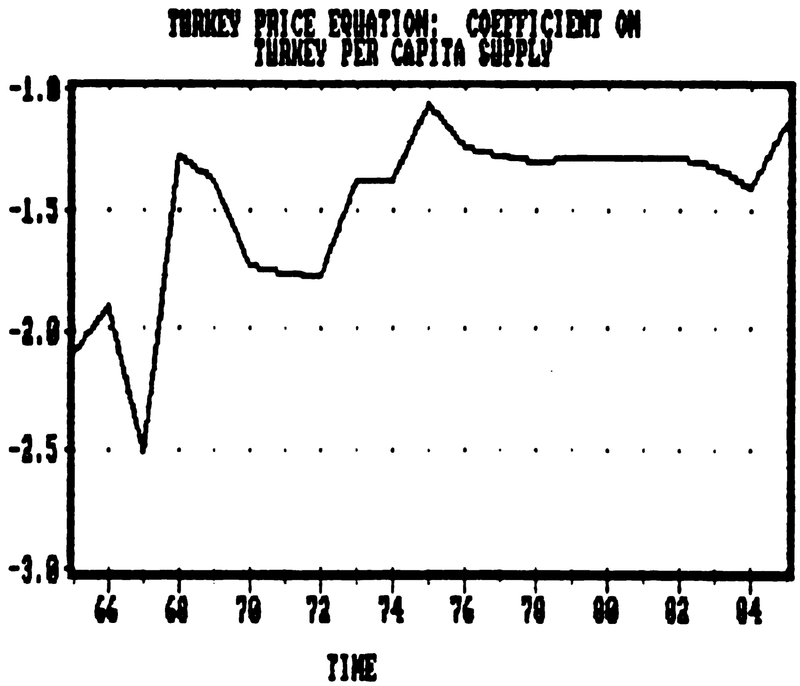


Figure 5.23

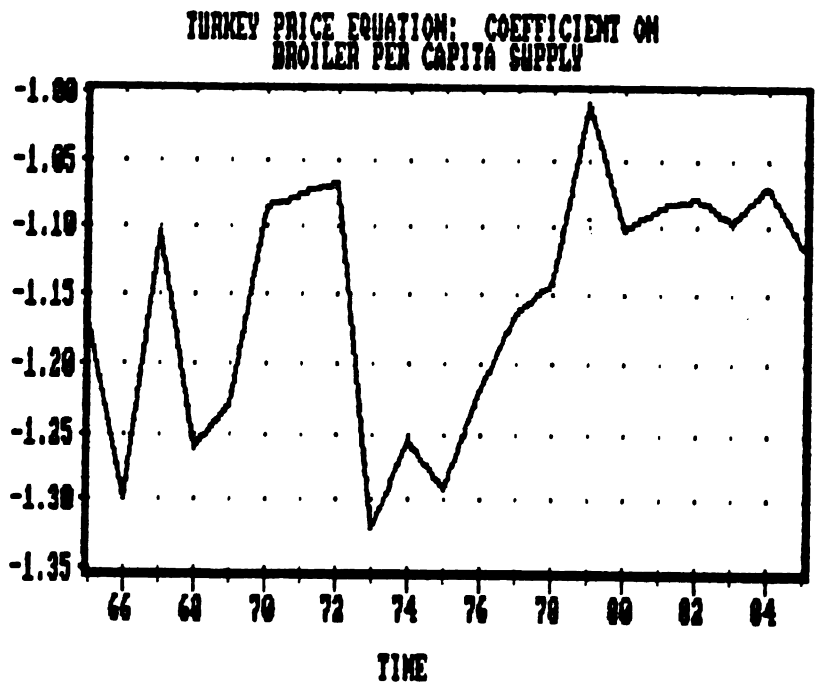


Figure 5.24

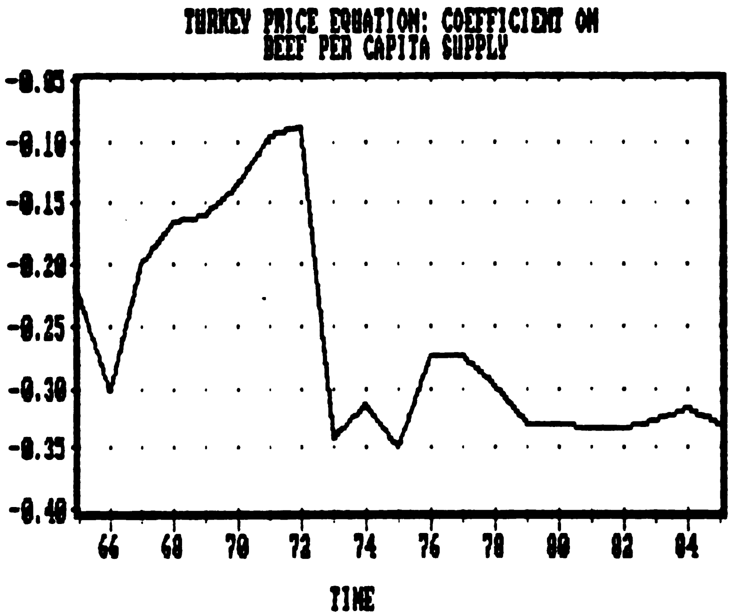


Figure 5.25

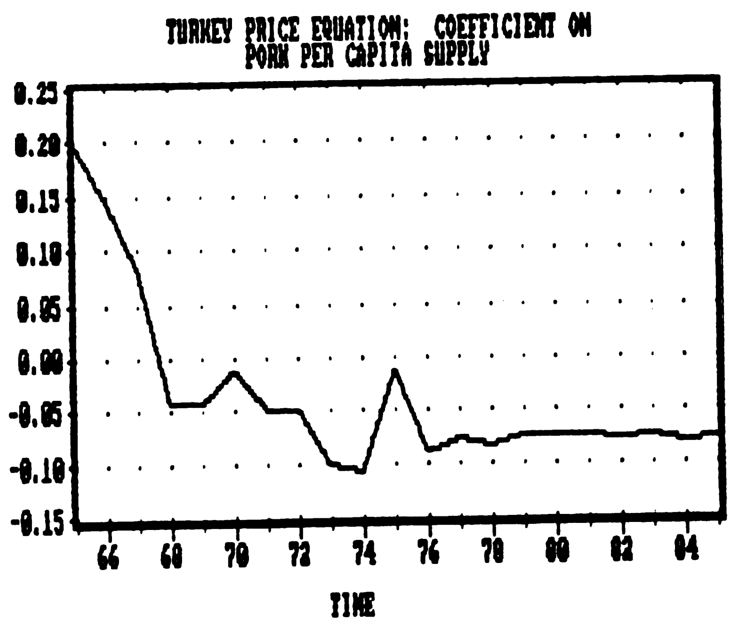


Figure 5.26

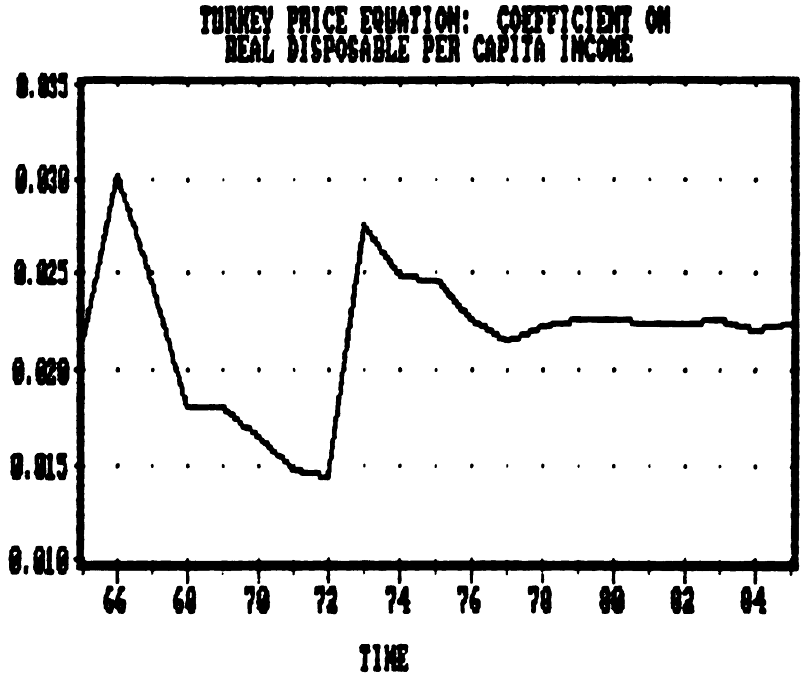


Figure 5.27

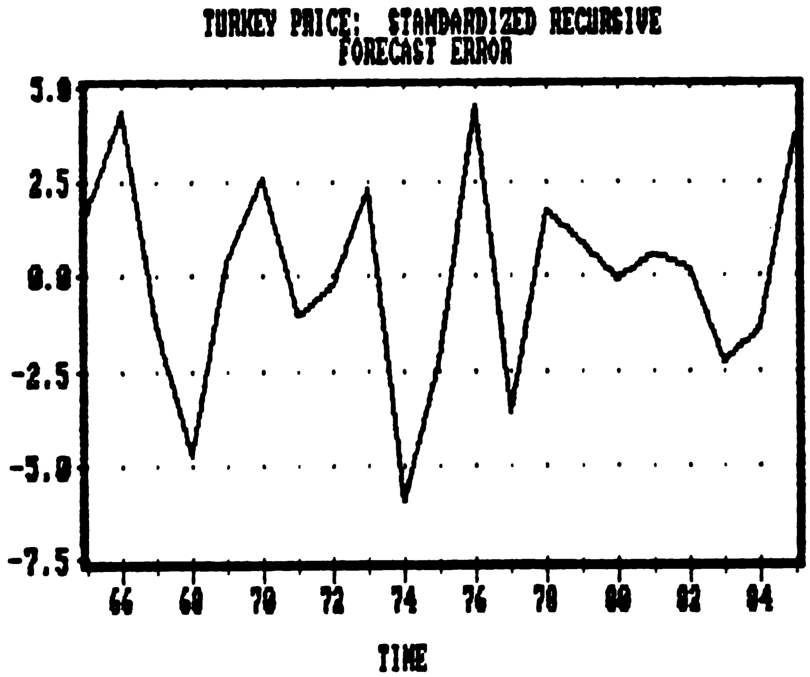


Table 5.13 Turkey Inverse Demand Equation: Recursive Residual Analysis
k = 1955-1961, r = 1962, 1963,...,1985

Year	Actual Value (cents.lb)	Recursive One-Step Ahead Forecast (cents/lb)	Forecast Error (cents.lb)	Variance of Forecast Error (dr)	Standardized Forecast Error (wr)
1962	23.84	23.49	0.35	7.055	0.050
1963	24.32	25.07	-0.75	2.286	-0.328
1964	22.60	21.29	1.31	2.329	0.562
1965	23.49	14.78	8.71	5.212	1.671
1966	23.76	19.46	4.30	1.003	4.287
1967	19.60	21.62	-2.02	1.578	-1.280
1968	19.67	25.29	-5.62	1.176	-4.779
1969	20.40	19.98	0.42	0.995	0.422
1970	19.43	17.21	2.22	0.839	2.646
1971	18.22	19.29	-1.07	1.053	-1.016
1972	17.72	17.93	-0.21	0.822	-0.255
1973	28.70	21.98	6.72	2.934	2.290
1974	18.96	22.80	-3.84	0.639	-6.009
1975	21.59	24.24	-2.65	1.240	-2.137
1976	18.65	14.85	3.80	0.846	4.492
1977	19.56	21.79	-2.23	0.626	-3.562
1978	22.31	21.08	1.23	0.710	1.732
1979	19.41	18.03	1.38	1.507	0.916
1980	16.21	16.22	-0.01	0.920	-0.011
1981	14.11	13.59	0.52	0.808	0.644
1982	13.66	13.51	0.15	0.813	0.184
1983	12.23	13.65	-1.42	0.629	-2.258
1984	15.30	16.35	-1.05	0.730	-1.438
1985	14.86	12.26	2.60	0.684	3.801

Figure 5.28

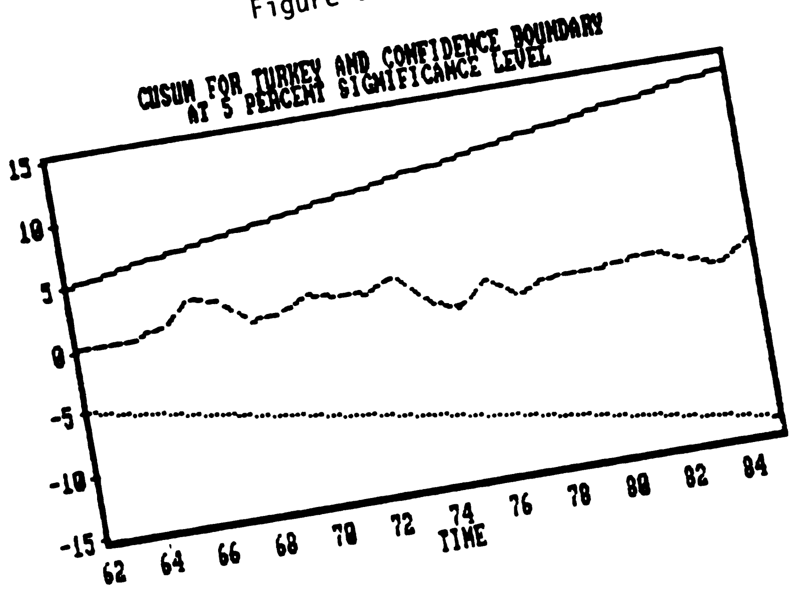
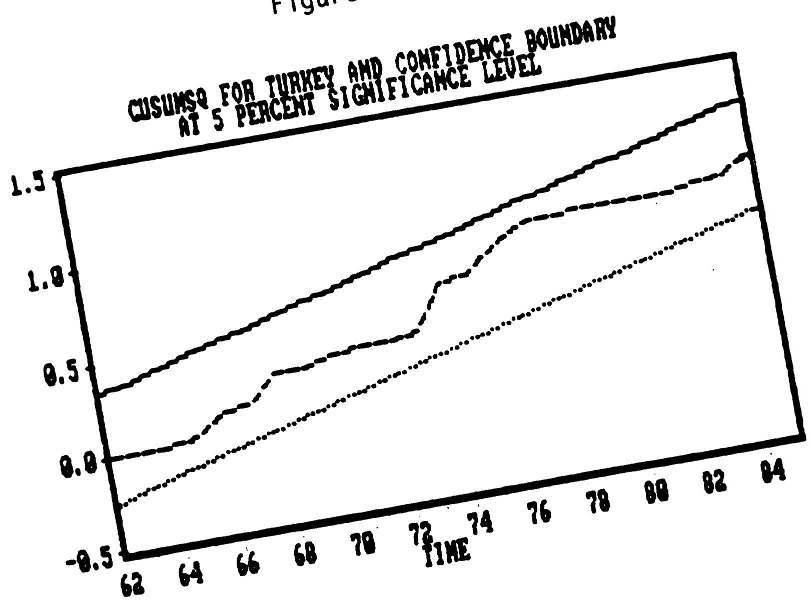


Figure 5.29



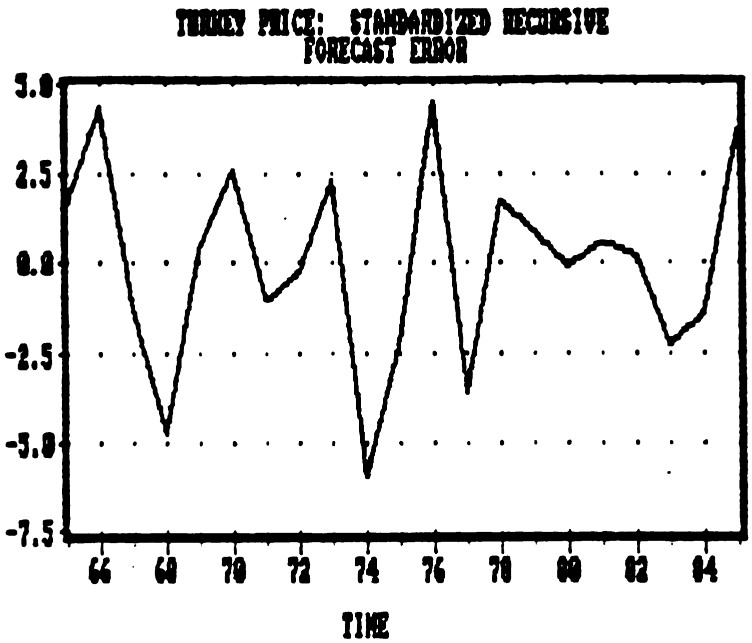
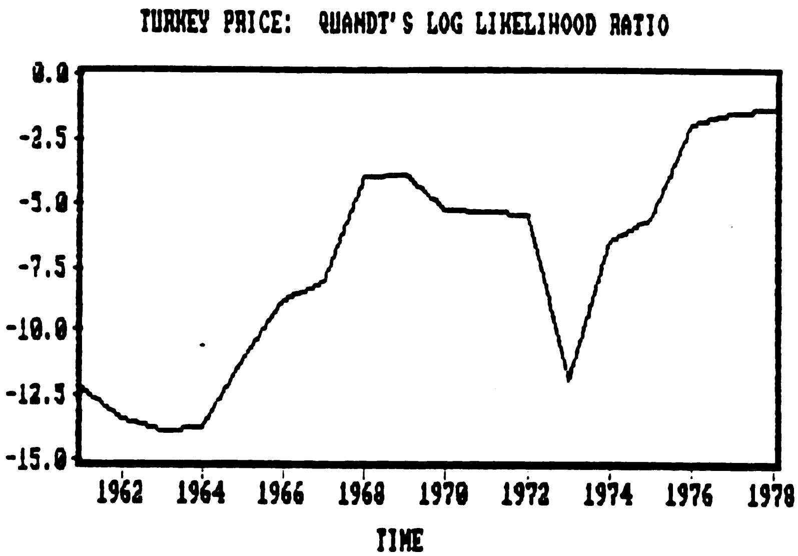

TURKEY PRICE: STANDARDIZED RECURSIVE
FORECAST ERROR
5.0
2.5
0.0
-2.5
-5.0
-7.5
66
68
70
72
74
76
78
80
82
84
TIME

Figure 5.30


TURKEY PRICE: QUANDT'S LOG LIKELIHOOD RATIO
0.0
-2.5
-5.0
-7.5
-10.0
-12.5
-15.0
1962
1964
1966
1968
1970
1972
1974
1976
1978
TIME

reaching 0.0215 in 1977. The coefficient then stabilized.

The recursive residuals for the turkey demand model are listed in Table 5.14 and plotted in Figure 5.27. The plot of the residuals does not indicate a systematic pattern. The residuals varied between 5.0 and -5.0 from the period 1955-65 to 1955-68. The variation narrowed to about 2.5 and -2.5 between 1969 and 1973. The recursive residuals then increased (in absolute value) to -6.0 in 1974 and then to 4.5 in 1976. The stability tests based on the one step ahead recursive residuals led to the failure to reject the null hypothesis of constant demand parameters. The location tests are not significant at the 0.05 level. The CUSUM and CUSUMSQ (Figure 5.28 and 5.29) including the heteroscedasticity tests are also not significant at the 0.05 level indicating a nonsignificant difference in the average size of the one step ahead recursive residuals.

The foregoing results indicate that we fail to reject the null hypothesis of stability in the parameters of inverse demand for turkey.

5.2 Demand Models with Time Trend and Dummy Variables: A Test of Gradual and Abrupt Structural Shifts

Based on the empirical results of the recursive residual analysis, the null hypothesis of constant parameters of the inverse demand for beef, pork and broilers is rejected against the alternative hypothesis of parameter instability. Information about possible points of discontinuity in the parameters were identified. In this section, the information on the timing of discontinuity in the parameters will be used in specifying the demand models to explicitly account for the changes in the demand parameters for the three commodities. Similar specification will be used in the case of turkey in order to assess whether results similar to those of constant parameter model will be found.

The base model of inverse demand for the four commodities specifies the price of the commodity as a function of the own quantity available for consumption, quantities of substitutes and income. In the specification, the residual term contains the influence of all variables except the quantities and income that affect the price of the product in question, including any changes in tastes or changes in other conditions. It is known that if the residual is correlated with either the quantities or income, regressions of the base model yield biased estimates of the coefficients on the variables correlated with the error term. For example, if the taste for the commodity is shifting at the same time that income is increasing, the estimated coefficient on income represents the combined effect of the shift in taste and increases in income. To reduced this problem of biased estimates, a time trend variable is introduced as a separate variable. The trend variables are introduced to test for gradual structural shifts in demand due to the hypothesized continous changes in tastes. If the model is linear in the variables, the coefficient on the time trend measures the rate of shift of demand in terms of annual prices, given quantities and income. The shift in demand is approximated by a smooth, steady, monotonic function of time. Several conceptual problems are recognized in the inclusion of a time trend (George and King, 1971). First, the trend variable is often highly correlated with prices and income. Hence, multicollinearity among these variables leads to inaccuracy in the estimates and the variance of the coefficients becomes larger. Second, the time trend is not able to capture possible cyclical changes in demand. It is more realistic to suppose that demand may decline for a while, then recover and increase over another series of years. This situation is considered in the latter part of the study.

Inverse demand equation were estimated for beef, pork, broilers and turkeys using time series data for 1955-85. The results were compared with a similar analysis for a more recent period of 1970-85. The demand parameters estimated from these models are compared with those estimated from the models augmented by the trend variables. All the equations were in linear form and were estimated by ordinary least squares. Where serial correlation is indicated, the AR1 procedure is used. The flexibilities are estimated at the means of the relevant variables.

5.2.1 Analysis of Results from Models without Trend Variables

The demand models estimated are specified as follows:

$$(5.1)\quad P_t = \beta_0 + \beta_1 Q_t + \sum_{k=2}^{n} \beta_k Q_{kt} + c_1 Y_t + d_1 DV_t + e_t$$

where P represents the real price of the commodity, Q's are the quantities available for consumption of the commodity in question and the quantities of substitutes, Y is real disposable income per capita, and DV stands for a shifter variable. DV is an indicator variable to test for abrupt discontinuity and change in demand. DV70on takes a value of zero before 1970 and one from 1970 to 1985. The models are estimated for the entire period (1955-1985) and then for a more recent time period (1970-85) without the dummy variable for comparative purposes. The statistical results are presented in Equations 5.1-5.8.

For beef, the flexibility estimates (see Table 5.15) are generated from Equation 5.1 and 5.2. The own-quantity flexibility (estimated from Equation 5.2) was found to be -1.78344 for the entire time period. For the period 1970-85, the own-quantity flexibility for beef increased (in absolute value) to -2.3105. A significantly positive income flexibility (1.37118) was estimated from the analysis for

Equation 5.1

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is FBP
Convergence achieved after 9 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	19.399898	171.57740	0.1130679	0.911
BFPC	-0.4549013	0.0815863	-5.5757082	0.000
POULPC	-0.0659843	0.1825021	-0.3615534	0.721
PKPC	-0.0804933	0.0758137	-1.0617251	0.299
DINC	0.0127803	0.0047483	2.6915692	0.013
DV70ON	-0.5596941	1.9552618	-0.2862502	0.777
AR(1)	0.9847574	0.0882206	11.162444	0.000

R-squared	0.771114	Mean of dependent var	26.34202
Adjusted R-squared	0.711405	S.D. of dependent var	3.457912
S.E. of regression	1.857626	Sum of squared resid	79.36783
Durbin-Watson stat	1.486483	F-statistic	12.91448
Log likelihood	-57.16159		

Equation 5.2

SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	96.943047	27.778306	3.4898833	0.005
BFPC	-0.5232701	0.1384182	-3.7803560	0.003
POULPC	-1.0276869	0.1957957	-5.2487722	0.000
PKPC	0.0160687	0.1529244	0.1050764	0.918
DINC	0.0136848	0.0058065	2.3568217	0.038

R-squared	0.784161	Mean of dependent var	25.38022
Adjusted R-squared	0.705675	S.D. of dependent var	4.083449
S.E. of regression	2.215343	Sum of squared resid	53.98518
Durbin-Watson stat	2.170348	F-statistic	9.991006
Log likelihood	-32.43198		

Equation 5.3

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is PPORK
Convergence achieved after 14 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	64.591304	21.286265	3.0344123	0.006
PKPC	-0.6990178	0.0888181	-7.8702181	0.000
BFPC	-0.2124539	0.0956387	-2.2214215	0.036
POULPC	-0.1142295	0.1976726	-0.5778720	0.569
DINC	0.0088019	0.0049271	1.7864229	0.087
DV70ON	-0.8570715	2.3531391	-0.3642248	0.719
AR(1)	0.9107558	0.1265517	7.1967098	0.000

R-squared	0.794677	Mean of dependent var	20.06686
Adjusted R-squared	0.741115	S.D. of dependent var	4.123312
S.E. of regression	2.097973	Sum of squared resid	101.2343
Durbin-Watson stat	1.902522	F-statistic	14.83646
Log likelihood	-60.81176		

Equation 5.4

SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	113.95430	20.731491	5.4966765	0.000
PKPC	-0.7109559	0.1141305	-6.2293250	0.000
BFPC	-0.3465470	0.1033042	-3.3546264	0.006
POULPC	-0.7680386	0.1461261	-5.2559979	0.000
DINC	0.0106905	0.0043335	2.4669377	0.031

R-squared	0.924601	Mean of dependent var	20.55728
Adjusted R-squared	0.897184	S.D. of dependent var	5.156257
S.E. of regression	1.653353	Sum of squared resid	30.06935
Durbin-Watson stat	2.174381	F-statistic	33.72279
Log likelihood	-27.75036		

Equation 5.5

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	46.795617	5.5574273	8.4203742	0.000
POULPC	-0.8490167	0.1051983	-8.0706307	0.000
BFPC	-0.3007146	0.0469803	-6.4008659	0.000
PKPC	-0.1260398	0.0722948	-1.7434141	0.094
DINC	0.0168086	0.0032847	5.1171910	0.000
DV700N	0.8484291	1.2173922	0.6969234	0.492

R-squared	0.911508	Mean of dependent var	15.11533
Adjusted R-squared	0.893809	S.D. of dependent var	4.831722
S.E. of regression	1.574509	Sum of squared resid	61.97695
Durbin-Watson stat	1.306052	F-statistic	51.50216
Log likelihood	-54.72511		

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is CHP
Convergence achieved after 4 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	42.288713	4.2730581	9.8965920	0.000
POULPC	-0.5307903	0.0782186	-6.7859882	0.000
BFPC	-0.1864537	0.0353832	-5.2695594	0.000
PKPC	-0.1709013	0.0463704	-3.6855666	0.001
DINC	0.0098118	0.0021236	4.6203224	0.000
DV700N	0.0688255	0.9245146	0.0744451	0.941
AR(1)	0.3608222	0.1044957	3.4529866	0.002

R-squared	0.952827	Mean of dependent var	14.57179
Adjusted R-squared	0.940521	S.D. of dependent var	3.830970
S.E. of regression	0.934313	Sum of squared resid	20.07763
Durbin-Watson stat	2.661718	F-statistic	77.42718
Log likelihood	-36.54429		

Equation 5.6

SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	44.883995	12.710834	3.5311606	0.005
POULPC	-0.5638105	0.0895924	-6.2930590	0.000
BFPC	-0.2016647	0.0633376	-3.1839667	0.009
PKPC	-0.1812610	0.0699754	-2.5903540	0.025
DINC	0.0103490	0.0026569	3.8950768	0.002

R-squared	0.876655	Mean of dependent var	12.24472
Adjusted R-squared	0.831802	S.D. of dependent var	2.471718
S.E. of regression	1.013699	Sum of squared resid	11.30345
Durbin-Watson stat	2.331362	F-statistic	19.54517
Log likelihood	-19.92317		

Equation 5.7

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is TKP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	51.419596	6.4197641	8.0095772	0.000
POULPC	-1.1157869	0.1215217	-9.1817879	0.000
BFPC	-0.3302287	0.0542702	-6.0849038	0.000
PKPC	-0.0783667	0.0835127	-0.9383810	0.357
DINC	0.0221611	0.0037944	5.8404704	0.000
DV70ON	0.1688525	1.4062929	0.1200692	0.905

R-squared	0.918347	Mean of dependent var	21.68232
Adjusted R-squared	0.902016	S.D. of dependent var	5.810502
S.E. of regression	1.818823	Sum of squared resid	82.70290
Durbin-Watson stat	2.418889	F-statistic	56.23474
Log likelihood	-59.19674		

Equation 5.8

SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is TKP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	56.213024	24.165222	2.3261953	0.040
POULPC	-1.0107178	0.1703288	-5.9339216	0.000
BFPC	-0.3181829	0.1204143	-2.6424003	0.023
PKPC	-0.1360195	0.1330338	-1.0224436	0.329
DINC	0.0196258	0.0050512	3.8853496	0.003

R-squared	0.830443	Mean of dependent var	18.18261
Adjusted R-squared	0.768785	S.D. of dependent var	4.007914
S.E. of regression	1.927196	Sum of squared resid	40.85494
Durbin-Watson stat	2.526591	F-statistic	13.46870
Log likelihood	-30.20253		

Table 5.14 Own Quantity, Cross Quantity, and Income Flexibility Estimates From Inverse Demand Models Without Trend Variables

	1955 - 1985				1970 - 1985			
	Beef Price	Pork Price	Broiler Price	Turkey Price	Beef Price	Pork Price	Broiler Price	Turkey Price
Q Beef	-1.7834	-1.0942	-1.2786	-1.5023	-2.3110	-1.8893	-1.8458	-1.8506
Q Pork	-0.1903	-2.1688	-0.7068	-0.1732	n.s.	-2.2203	-0.9503	-0.2015
Q Poultry	-0.1198	-0.2722	-1.6839	-2.4300	-2.3056	-2.1271	-2.6215	-3.3205
Income	1.3712	1.2392	1.8396	2.8273	1.7559	1.6933	2.7520	3.6486

Flexibilities are calculated at the means the entire 1955-85 period. A slightly higher and significant positive income flexibility was estimated for the 1970-85 period.

The increase in the income flexibility is in response to a slightly higher coefficient on the income variable and the higher income average and lower average beef price in the 1970-85 period. The cross-flexibility of beef with respect to broilers increased significantly in the second period. This is in support of the hypothesis of increasing substitutability of poultry with beef starting sometime in the 1970s and through the 1980s.

The income flexibility of demand for pork slightly increased from 1.23918 in the 1955-85 (Equation 5.3) period to 1.69335 in the 1970-85 period (Equation 5.4). The own-quantity flexibility of demand for pork is almost the same in the two periods. A significant increase in the cross-flexibility of pork with respect to poultry is observed, from -0.27218 in 1955-85 to -2.127135 in 1970-85.

For broilers, the income flexibility was also higher in the 1970-85 period than in the entire 1955-85 period. The own-quantity flexibility of demand for broilers likewise increased in 1970-85. A slight increase in the cross-flexibility of broilers with respect to beef and pork was also observed in the 1970-85 period.

The income flexibility for turkey was significant and positive during the two time periods. It increased from

2.827 in 1955-85 to 3.649 in 1970-85. Likewise, the own-quantity flexibility for turkey increased from -2.430 in 1955-85 to -3.321 in 1970-85. A slight increase in the cross flexibility of turkey with respect to beef is observed. The cross-flexibility with respect to pork slightly increased but was not significant at the 0.05 level.

5.2.2 Analysis of Demand Models with Trend Variables

As indicated in the results of the recursive residual analysis, a discontinuity in the demand parameters for beef, pork and broilers occured sometime near late 1970s. In the case of beef, pork, and broilers, the recursive residuals indicate a possible structural shift sometime in 1976-77.

Using this information as the timing of the structural change in demand, the base model for each commodity is augmented by two trend variables. One trend variable represents the trend from 1955-76 is labelled T5576, and another to represent the turning point in the trend from 1977 to date.[5]

The estimated models are presented in Equations 5.9 to 5.16. The associated flexibility estimates are presented

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[5] This procedure is used by Ferris (1985) in a study of demand for meat.

in Table 5.16. In contrast to the results from the models without the trend variables, the income flexibility on pork was very close in the two time periods though higher in magnitude in both periods. The own-quantity flexibility of demand for pork increased from -1.8768 in 1955-85 (estimated from equation 5.9) to -2.6041 in 1970-85 (estimated from equation 5.10). These estimates are slightly higher than in Table 5.15. The cross flexibility of pork with respect to beef also increased in the second period and are higher than those estimated without the trend variables. The cross flexibility of pork with respect to poultry increased in 1970-85 but is lower than those estimated in Table 5.15. The lower value of the cross flexibility is due to the correlation between time and quantity of poultry available for consumption. The results indicate an absence of a significant trend before 1976 and a presence of a significant negative trend starting in 1977.

The estimates of the own-flexibility of broiler demand remained quite the same between 1955-85 (Equation 5.13) and 1970-85 (Equation 5.14). These estimates were somewhat lower than in Table 5.15, again possibly due to the multicollinearity between the quantities and time. The income flexibility of broiler slightly increased from 2.0165 in 1955-85 to 2.7967 in 1970-85. The estimates of the cross flexibility with respect to beef and pork likewise increased in 1970-85.

Equation 5.9

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	39.450968	8.6788701	4.5456341	0.000
BFPC	-0.5862137	0.0434441	-13.493517	0.000
PKPC	0.0002278	0.0460524	0.0049460	0.996
POULPC	0.0962027	0.1095527	0.8781406	0.389
DINC	0.0164880	0.0022286	7.3982169	0.000
T5576	-0.0394448	0.1753647	-0.2249299	0.824
T77ON	-2.7012587	0.2413120	-11.194049	0.000

R-squared	0.936550	Mean of dependent var	26.41577
Adjusted R-squared	0.920687	S.D. of dependent var	3.424503
S.E. of regression	0.964426	Sum of squared resid	22.32281
Durbin-Watson stat	2.249104	F-statistic	59.04163
Log likelihood	-38.89723		

Equation 5.10

SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	52.407726	17.940135	2.9212560	0.017
BFPC	-0.6188976	0.0750484	-8.2466506	0.000
PKPC	-0.0814293	0.0919638	-0.8854487	0.399
POULPC	0.0875820	0.2464693	0.3553464	0.731
DINC	0.0152004	0.0033019	4.6035209	0.001
T5576	-0.2112829	0.2839251	-0.7441502	0.476
T77ON	-2.5589166	0.4828197	-5.2999422	0.000

R-squared	0.950915	Mean of dependent var	25.38022
Adjusted R-squared	0.918191	S.D. of dependent var	4.083449
S.E. of regression	1.167959	Sum of squared resid	12.27715
Durbin-Watson stat	2.366440	F-statistic	29.05900
Log likelihood	-20.58423		

Equation 5.11
SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	46.498746	13.674786	3.4003272	0.002
PKPC	-0.6049325	0.0725620	-8.3367642	0.000
BFPC	-0.2851576	0.0684523	-4.1657849	0.000
POULPC	-0.0876013	0.1726158	-0.5074931	0.616
DINC	0.0168346	0.0035116	4.7940520	0.000
T5576	-0.0030672	0.2763118	-0.0111004	0.991
T770N	-1.7736990	0.3802212	-4.6649139	0.000

R-squared	0.888321	Mean of dependent var	20.12544
Adjusted R-squared	0.860401	S.D. of dependent var	4.067107
S.E. of regression	1.519589	Sum of squared resid	55.41963
Durbin-Watson stat	1.772682	F-statistic	31.81696
Log likelihood	-52.99177		

Equation 5.12
SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is PPORK
Convergence achieved after 4 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	111.15304	14.279057	7.7843400	0.000
PKPC	-0.8338929	0.0718704	-11.602729	0.000
BFPC	-0.5229934	0.0542122	-9.6471562	0.000
POULPC	-0.2780987	0.2377967	-1.1694810	0.276
DINC	0.0127085	0.0019573	6.4930272	0.000
T5576	0.0292293	0.2076960	0.1407310	0.892
T770N	-1.4175877	0.4180564	-3.3909004	0.009
AR(1)	-0.7415230	0.2502366	-2.9632874	0.018

R-squared	0.980447	Mean of dependent var	20.55728
Adjusted R-squared	0.963338	S.D. of dependent var	5.156257
S.E. of regression	0.987285	Sum of squared resid	7.797859
Durbin-Watson stat	2.134412	F-statistic	57.30612
Log likelihood	-16.95310		

Equation 5.13
SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is CHP
Convergence achieved after 4 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	36.760647	9.9939519	3.6782893	0.001
POULPC	-0.4120323	0.1201034	-3.4306468	0.002
BFPC	-0.2119077	0.0480934	-4.4061752	0.000
PKPC	-0.1798513	0.0464019	-3.8759438	0.001
DINC	0.0107553	0.0025673	4.1893268	0.000
T5576	-0.1115872	0.1976698	-0.5645131	0.578
T77ON	-0.3365768	0.2754721	-1.2218181	0.235
AR(1)	0.3831503	0.1012111	3.7856532	0.001

R-squared	0.955945	Mean of dependent var	14.57179
Adjusted R-squared	0.941927	S.D. of dependent var	3.830970
S.E. of regression	0.923196	Sum of squared resid	18.75042
Durbin-Watson stat	2.763068	F-statistic	68.19651
Log likelihood	-35.51843		

Equation 5.14
SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is CHP
Convergence achieved after 4 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	38.184611	16.059818	2.3776491	0.045
POULPC	-0.2930620	0.2410946	-1.2155480	0.259
BFPC	-0.2387859	0.0678345	-3.5201239	0.008
PKPC	-0.2361547	0.0837534	-2.8196419	0.023
DINC	0.0105173	0.0027052	3.8878651	0.005
T5576	-0.0930180	0.2385205	-0.3899790	0.707
T77ON	-0.6034533	0.4533272	-1.3311648	0.220
AR(1)	-0.2411299	0.3641267	-0.6622143	0.526

R-squared	0.905967	Mean of dependent var	12.24472
Adjusted R-squared	0.823688	S.D. of dependent var	2.471718
S.E. of regression	1.037861	Sum of squared resid	8.617249
Durbin-Watson stat	2.097844	F-statistic	11.01095
Log likelihood	-17.75243		

Equation 5.15

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is TKP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	26.596217	15.842400	1.6787998	0.106
POULPC	-0.9039149	0.1999775	-4.5200840	0.000
BFPC	-0.3148856	0.0793028	-3.9706736	0.001
PKPC	-0.1075442	0.0840640	-1.2793143	0.213
DINC	0.0262593	0.0040682	6.4548013	0.000
T5576	-0.5249419	0.3201105	-1.6398772	0.114
T770N	-0.3743058	0.4404907	-0.8497474	0.404

R-squared	0.926563	Mean of dependent var	21.68232
Adjusted R-squared	0.908204	S.D. of dependent var	5.810502
S.E. of regression	1.760462	Sum of squared resid	74.38142
Durbin-Watson stat	2.340006	F-statistic	50.46834
Log likelihood	-57.55299		

Equation 5.16

SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is TKP
Convergence achieved after 3 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	6.8849534	20.860036	0.3300547	0.750
POULPC	-0.1090912	0.3396444	-0.3211926	0.756
BFPC	-0.3231903	0.0841804	-3.8392565	0.005
PKPC	-0.2414971	0.1190202	-2.0290442	0.077
DINC	0.0224392	0.0030271	7.4126696	0.000
T5576	-0.8291894	0.3139213	-2.6413923	0.030
T770N	-1.7511693	0.6092170	-2.8744589	0.021
AR(1)	-0.5579115	0.3328708	-1.6760602	0.132

R-squared	0.935839	Mean of dependent var	18.18261
Adjusted R-squared	0.879698	S.D. of dependent var	4.007914
S.E. of regression	1.390127	Sum of squared resid	15.45962
Durbin-Watson stat	2.243510	F-statistic	16.66949
Log likelihood	-22.42816		

Table 5.15 Own Quantity, Cross Quantity and Income Flexibility Estimates From Inverse Demand Models With Trend Variables

	1955 - 1985				1970 - 1985			
	Beef Price	Pork Price	Broiler Price	Turkey Price	Beef Price	Pork Price	Broiler Price	Turkey Price
Q Beef	-2.3000	-1.4686	-1.4531	-1.5053	-2.7329	-2.8513	-2.1856	-1.9920
Q Pork	0.0004	-1.8768	-0.7430	-0.3097	-0.2059	-2.6041	-1.2381	-0.8526
Q Poultry	0.1746	-0.2087	-1.3072	-1.9991	0.1964	-0.7702	-1.3626	-0.3416
Income	1.7700	2.3706	2.0165	3.4322	1.9500	2.0130	2.7968	4.0184

Flexibilities are calculated at the means

With trend factors, the income flexibility of demand for turkeys increased between 1955-85 (Equation 5.15) and 1970-85, (Equation 5.16) and were somewhat higher than those estimated from the model without trend factors. The trend effects are both significant and negative but is highly collinear with the quantity of poultry. The own-quantity flexibility of demand for turkeys declined between the two periods and was lower than those estimated without the trend effects. The cross flexibility of demand for turkeys with respect to beef and pork both increased between the two periods.

5.3 Varying Parameter Models Using Legendre Polynomials

Continous variation in the inverse demand parameters for beef, pork and broilers was tested by specifying a varying parameter model with Legendre polynomials. The specification of the inverse demand models follows the equation presented in section 4.5.5.1. The theoretical foundations of the approach was briefly discussed in section 4.5.5. By introducing varying degree Legendre polynomials, the specification allows the demand parameters to vary over time.

The models are linear in parameters and were estimated using ordinary least squares. The models are evaluated using standard statistical tests.

The empirical results of selected equations for the commodities are presented in Equations 5.17-5.48. Linear, quadratic, and cubic Legendre polynomial specification for the own quantity, quantity of substitutes, and income variables were tested. The corresponding own-quantity, cross, and income flexibilities were estimated and analyzed for each commodity.

In general, the results indicate that the null hypothesis of constant parameters of the inverse demand models for the three commodities can be rejected at the .01 level based on the F-tests. It is observed that by specifying the demand coefficients as continous functions of time by introducing Legendre polynomials, serial correlation in all the demand models was reduced. A higher degree polynomial tended to increase the adjusted coefficient of determination and is correlated with the other explanatory variables. Hence, the specification of equations with a high degree polynomial is done with caution. In this study, a sign change or a reduction in a formerly significant coefficient after the introduction of a higher degree polynomial is an indication of potential collinearity of the polynomial with the variable whose coefficient changes sign. In this situation, a lower degree polynomial specification is preferred and chosen for evaluation and further analysis.

The own, cross, and income flexibilities over time for the three commodities were estimated using the formula presented in equation 5 in section 4.5.5.1. These estimated flexibilities are presented in tables following each equation.

5.3.1 Beef Demand Model with Legendre Polynomial

The own quantity flexibilities for beef estimated from the Legendre polynomial models indicate flexible price response to changes in beef quantity available for consumption, other factors constant (Figure 5.31-5.34). The estimated income flexibilities for beef indicate a more than proportionate change in beef prices in response to a one percent change in real disposable income. As expected, the income flexibility estimates are positive. This is because prices move directly with changes or shifts in demand. A higher level of income is associated with a higher demand until a leveling off or saturation is reached where a certain percent increase in income will result in a less than proportionate increase in demand.

In contrast with the constant parameter inverse demand model for beef the varying parameter model with cubic Legendre polynomial has better statistical properties. In particular, the Durbin-Watson statistic indicates no serial correlation in the varying parameter model. The fit of the model was materially improved and all the coefficients have signs consistent with theory.

The own quantity flexibilities estimated from the models with quadratic and cubic Legendre polynomials exhibit the same general pattern of year to year variation (see Figure 5.31 and 5.32). This is a good indication of the consistency of the estimation and specification of the models.

The flexibilities exhibit a slight upward trend (in absolute value) during the whole period. A structural break is indicated by larger fluctuations in the own-quantity flexibilities for beef starting sometime in the mid-1970s.

The pattern of the estimated own-quantity flexibilities for beef may be related to the pattern of production cycles during the period of analysis. During the period 1964 to 1970, the own-quantity flexibilities varied only slightly. Starting in 1970, they exhibited a slight downward trend until about 1973. With the slight increase in quantities available for consumption and rising prices, the own quantity flexibilities declined during the 1970-73 period. The lower magnitude of the flexibility estimate in 1973 reflect the high beef prices in 1973. The record prices in 1973 is associated with producers decision to withhold animals from slaughter for herd expansion. Due to the slow rate of biological reproduction, beef production can be increased only by withholding animals from current slaughter for further fattening or to increase the size of the breeding herd. Animal slaughter increased thereafter and

Equation 5.17

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	66.450758	11.155087	5.9569915	0.000
BFPC	-0.5954262	0.0728896	-8.1688739	0.000
P1QB	0.0295225	0.0355982	0.8293250	0.415
P2QB	-0.0836551	0.0114760	-7.2895587	0.000
PKPC	-0.0243737	0.0748837	-0.3254876	0.748
POULPC	-0.6341983	0.1356594	-4.6749296	0.000
DINC	0.0188678	0.0035981	5.2437780	0.000

R-squared	0.845181	Mean of dependent var	26.41577
Adjusted R-squared	0.806476	S.D. of dependent var	3.424503
S.E. of regression	1.506485	Sum of squared resid	54.46792
Durbin-Watson stat	1.830734	F-statistic	21.83661
Log likelihood	-52.72328		

Equation 5.18

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	52.973442	8.7947058	6.0233330	0.000
BFPC	-0.5812352	0.0541794	-10.727972	0.000
P1QB	-0.0390648	0.0304362	-1.2834981	0.212
P2QB	-0.0789738	0.0085783	-9.2062733	0.000
P3QB	-0.0308378	0.0067971	-4.5369258	0.000
PKPC	-0.0971113	0.0578353	-1.6791005	0.107
POULPC	-0.1509152	0.1465644	-1.0296854	0.314
DINC	0.0166589	0.0027141	6.1379071	0.000

R-squared	0.918299	Mean of dependent var	26.41577
Adjusted R-squared	0.893433	S.D. of dependent var	3.424503
S.E. of regression	1.117914	Sum of squared resid	28.74382
Durbin-Watson stat	1.913656	F-statistic	36.93054
Log likelihood	-42.81585		

beef prices declined. This situation of declining prices and increasing quantity available for consumption is reflected in the upward trend of the own-quantity flexibility estimates starting in 1973 through 1977. Own flexibility estimates subsequently declined until 1979 due to the decline in quantity available for consumption and the increase in real beef prices following liquidation of the breeding herd in earlier period.

Beef quantity available for consumption per person was relatively constant thereafter, (1979-1984), while real prices declined. The demand for beef shifted to the left and the own- quantity flexibilities trended upward during this period. During this period of declining demand for beef, large price adjustments are required in response to small changes in quantities; hence, increases in the own-quantity flexibilities for beef. To the extent that an inelastic demand is consistent with a flexible price, these results are consistent with other studies which found the demand for beef becoming more inelastic during the late 1970s (Chavas, 1983; Ferris, 1985).

Variation in the price response to income changes (income flexibility) was tested by augmenting the cubic Legendre polynomial model with a linear polynomial on the

Figure 5.31

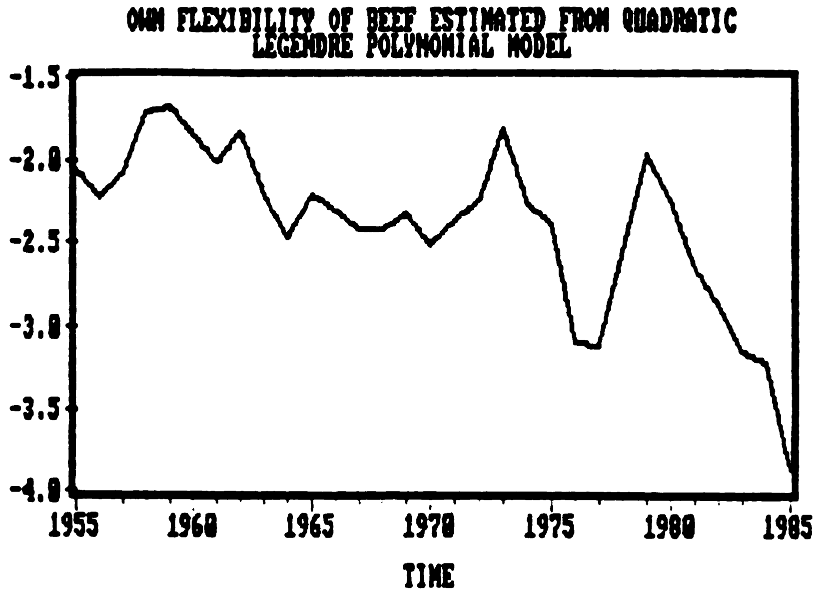
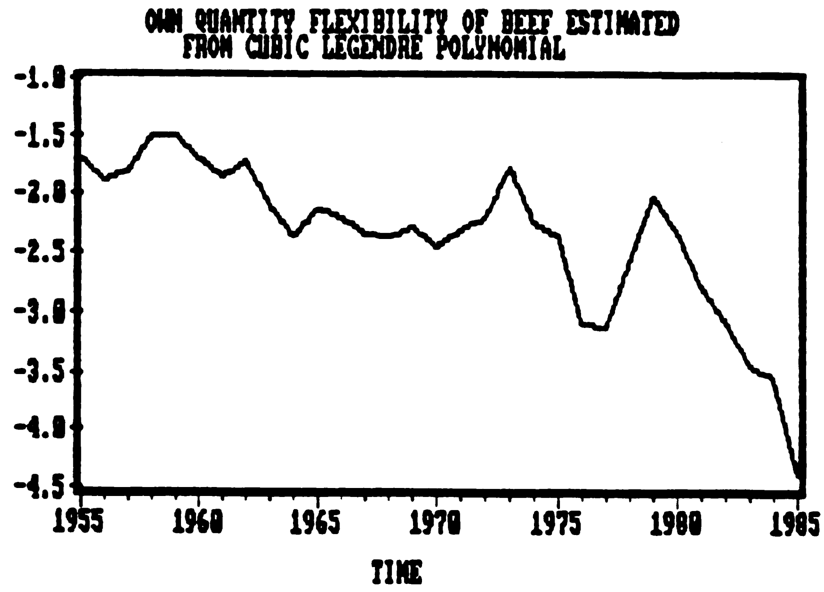


Figure 5.32



Equation 5.19

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	41.039137	9.6174577	4.2671503	0.000
BFPC	-0.6301993	0.0541868	-11.630136	0.000
P1QB	0.2382349	0.1243361	1.9160562	0.068
P2QB	-0.0473322	0.0159134	-2.9743586	0.007
P3QB	-0.0188062	0.0081634	-2.3037241	0.031
PKPC	-0.0574429	0.0558993	-1.0276142	0.315
POULPC	-0.0940289	0.1369518	-0.6865838	0.500
DINC	0.0214588	0.0032584	6.5855757	0.000
P1Y	-0.0113831	0.0049732	-2.2889001	0.032

R-squared	0.934013	Mean of dependent var	26.41577
Adjusted R-squared	0.910018	S.D. of dependent var	3.424503
S.E. of regression	1.027250	Sum of squared resid	23.21534
Durbin-Watson stat	1.993359	F-statistic	38.92485
Log likelihood	-39.50490		

Equation 5.20

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	42.265962	13.300433	3.1777884	0.005
BFPC	-0.6111378	0.0737157	-8.2904720	0.000
P1QB	0.2257077	0.0737580	3.0601117	0.006
P2QB	-0.0445743	0.0317915	-1.4020823	0.175
PKPC	0.0366801	0.0741156	0.4949031	0.626
P1PK	-0.1205698	0.1534445	-0.7857555	0.441
POULPC	-0.2345571	0.1885974	-1.2436921	0.227
P1POUL	-0.4215605	0.2417844	-1.7435393	0.096
DINC	0.0205081	0.0033496	6.1225593	0.000

R-squared	0.889393	Mean of dependent var	26.34202
Adjusted R-squared	0.847258	S.D. of dependent var	3.457912
S.E. of regression	1.351431	Sum of squared resid	38.35366
Durbin-Watson stat	1.811524	F-statistic	21.10777
Log likelihood	-46.25294		

income variable (Equation 5.19). Allowing the income coefficient to vary over time contributed materially to the fit of the equation. The Durbin-Watson statistic indicates the further reduction of serial correlation. However, slight changes in the magnitudes of the coefficients of the polynomials and sign change in the coefficient of the linear polynomial on beef quantity are noted. Despite these changes, the own-quantity flexibility estimates from the augmented model exhibit the same pattern of year to year variation as those estimated from the quadratic and cubic models without the polynomial on income. In contrast to the own-quantity flexibility estimates from the latter models, the estimates from the augmented model are slightly larger (in absolute values) prior to 1973 and slightly smaller after 1973. The values of the flexibility estimates from the three models for the 1973 period were very close.

The estimates of beef price response to income changes varied over the period (Figure 5.34). Income flexibilities trended upward during 1959 through mid 1960s, then trended downward until 1973 and increased again thereafter until 1977. These estimates then sharply declined between 1977 and 1979 and steadily increased during the early 1980s.

Starting in mid 1970s, the pattern of income flexibility estimates is positively correlated with changes in per capita real disposable income. That is, declining income flexibility during the period 1977-79 is associated

Figure 5.33

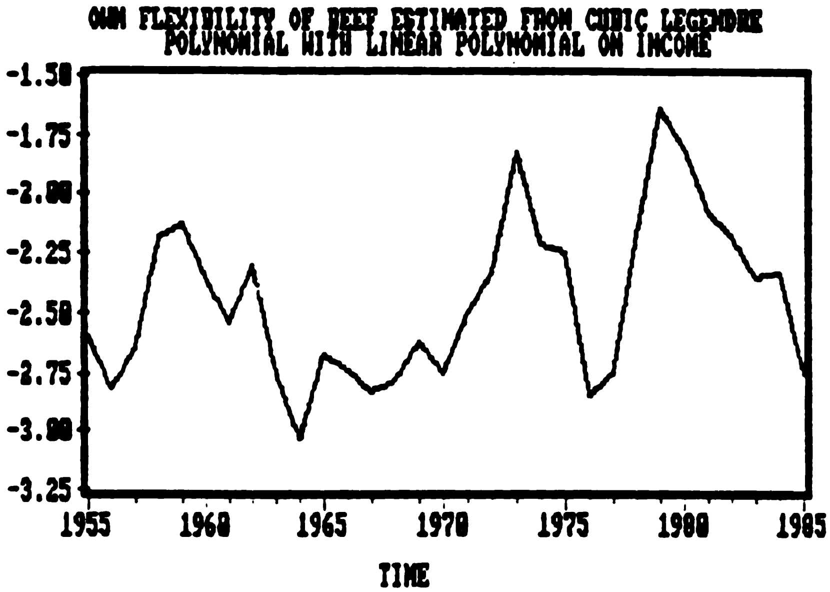
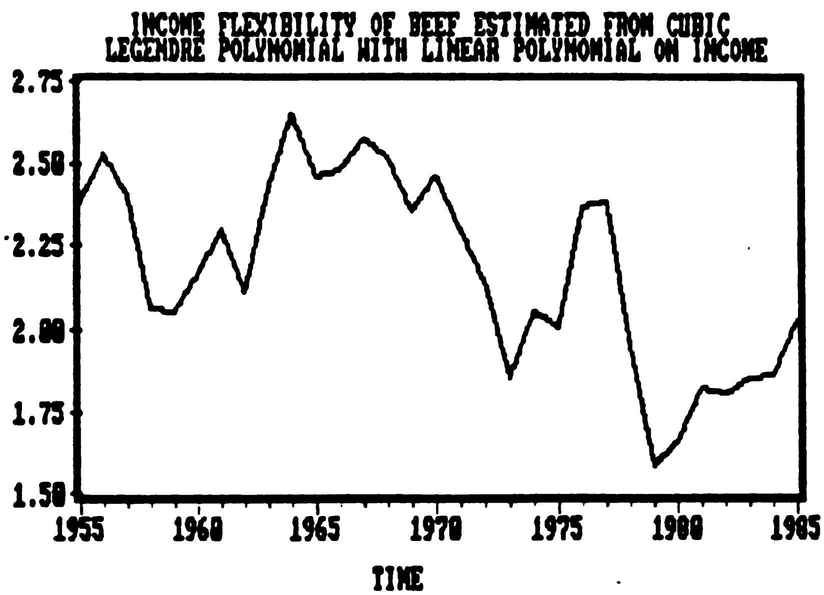


Figure 5.34



Equation 5.21

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	39.649798	8.4671594	4.6827744	0.000
BFPC	-0.6094849	0.0465080	-13.104935	0.000
P1QB	0.1932906	0.0465530	4.1520562	0.000
P2QB	0.1195201	0.0353293	3.3830325	0.003
PKPC	0.0140194	0.0492183	0.2848405	0.779
P1PK	-0.1002526	0.0977747	-1.0253427	0.317
POULPC	-0.0282791	0.1264760	-0.2235925	0.825
P1POUL	-0.3469288	0.1355049	-2.5602669	0.019
P2POUL	-0.3287105	0.0603076	-5.4505630	0.000
DINC	0.0188573	0.0021292	8.8564310	0.000
DV77ON	-3.6499762	0.9312053	-3.9196258	0.001

R-squared	0.958826	Mean of dependent var	26.41577
Adjusted R-squared	0.938240	S.D. of dependent var	3.424503
S.E. of regression	0.851044	Sum of squared resid	14.48553
Durbin-Watson stat	2.547486	F-statistic	46.57492
Log likelihood	-32.19412		

Equation 5.22

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	36.197146	10.928047	3.3123161	0.003
BFPC	-0.6002113	0.0602744	-9.9579748	0.000
P1QB	0.1605926	0.0594330	2.7020766	0.013
P2QB	0.0615042	0.0416286	1.4774511	0.154
PKPC	-0.0188613	0.0629351	-0.2996947	0.767
P1PK	-0.2235207	0.1201379	-1.8605340	0.077
POULPC	-0.0062436	0.1639632	-0.0380792	0.970
P1POUL	-0.1907648	0.1680696	-1.1350345	0.269
P2POUL	-0.2668927	0.0755365	-3.5332926	0.002
DINC	0.0194288	0.0027566	7.0482160	0.000

R-squared	0.927198	Mean of dependent var	26.41577
Adjusted R-squared	0.895997	S.D. of dependent var	3.424503
S.E. of regression	1.104383	Sum of squared resid	25.61292
Durbin-Watson stat	2.092636	F-statistic	29.71711
Log likelihood	-41.02829		

Equation 5.23

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	38.803168	9.0649098	4.2805906	0.000
BFPC	-0.6222738	0.0528662	-11.770738	0.000
P1QB	0.2389048	0.0953270	2.5061622	0.022
P2QB	0.1090847	0.0413721	2.6366741	0.017
PKPC	0.0121055	0.0514746	0.2351750	0.817
P1PK	-0.0959716	0.1102353	-0.8706068	0.395
POULPC	-0.0393886	0.1366064	-0.2883364	0.776
P1POUL	-0.2732382	0.2018283	-1.3538152	0.193
P2POUL	-0.3039981	0.0836548	-3.6339600	0.002
DINC	0.0198899	0.0028045	7.0920419	0.000
P1Y	-0.0032447	0.0054117	-0.5995804	0.556
DV77ON	-3.4177339	1.0466094	-3.2655297	0.004

R-squared	0.959079	Mean of dependent var	26.34202
Adjusted R-squared	0.934072	S.D. of dependent var	3.457912
S.E. of regression	0.887870	Sum of squared resid	14.18963
Durbin-Watson stat	2.482904	F-statistic	38.35211
Log likelihood	-31.33786		

Equation 5.24

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	39.425885	9.8248780	4.0128625	0.001
BFPC	-0.6180008	0.0543541	-11.369905	0.000
P1QB	0.1048129	0.0611437	1.7142078	0.102
P2QB	-0.0738255	0.0243903	-3.0268380	0.007
P3QB	-0.0285492	0.0066093	-4.3195576	0.000
PKPC	-0.0392347	0.0573832	-0.6837314	0.502
P1PK	-0.2109774	0.1150140	-1.8343630	0.082
POULPC	0.0557089	0.1543932	0.3608245	0.722
P1POUL	-0.1159362	0.1917352	-0.6046682	0.552
DINC	0.0181049	0.0025307	7.1541572	0.000

R-squared	0.942778	Mean of dependent var	26.34202
Adjusted R-squared	0.917028	S.D. of dependent var	3.457912
S.E. of regression	0.996048	Sum of squared resid	19.84225
Durbin-Watson stat	2.460136	F-statistic	36.61271
Log likelihood	-36.36740		

Equation 5.25

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is FBP
Convergence achieved after 3 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	36.891196	7.9239001	4.6556867	0.000
BFPC	-0.6192847	0.0433921	-14.271836	0.000
P1QB	0.1996924	0.0392639	5.0859069	0.000
P2QB	0.1231001	0.0329573	3.7351374	0.002
PKPC	0.0255442	0.0458912	0.5566248	0.585
P1PK	-0.1077969	0.1002752	-1.0750107	0.297
POULPC	-0.0199570	0.1344478	-0.1484366	0.884
P1POUL	-0.3702167	0.1495102	-2.4761961	0.023
P2POUL	-0.3337640	0.0558393	-5.9772266	0.000
DINC	0.0198173	0.0017990	11.015772	0.000
DV77ON	-3.4182330	0.7658849	-4.4631158	0.000
AR(1)	-0.3894227	0.2409052	-1.6164978	0.123

R-squared	0.963326	Mean of dependent var	26.34202
Adjusted R-squared	0.940914	S.D. of dependent var	3.457912
S.E. of regression	0.840535	Sum of squared resid	12.71699
Durbin-Watson stat	2.346131	F-statistic	42.98280
Log likelihood	-29.69428		

Equation 5.26

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is FBP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	54.332691	11.961568	4.5422716	0.000
BFPC	-0.5671045	0.0556908	-10.183093	0.000
P1QB	0.1617291	0.0551907	2.9303682	0.008
P2QB	0.1070928	0.0372447	2.8753804	0.009
PKPC	-0.0629290	0.0621675	-1.0122490	0.324
POULPC	-0.0318506	0.1467939	-0.2169749	0.830
P1QC	-0.2366728	0.1268768	-1.8653745	0.077
P2QC	-0.2308815	0.0712162	-3.2419782	0.004
DINC	0.0146307	0.0029635	4.9370476	0.000
DV73ON	105.53152	30.930956	3.4118416	0.003
DVT73	-1.4578048	0.4255210	-3.4259292	0.003

R-squared	0.946659	Mean of dependent var	26.41577
Adjusted R-squared	0.919989	S.D. of dependent var	3.424503
S.E. of regression	0.968662	Sum of squared resid	18.76613
Durbin-Watson stat	2.465198	F-statistic	35.49485
Log likelihood	-36.20713		

with declining income during the same period. Thereafter, income flexibility estimates increased as income increased until 1981. Estimates of income flexibility during 1981-82 slightly declined as income declined during that period. During the last three years, income flexibility estimates steadily increased with steady increases in real disposable income.

The decline in the income elasticity for beef during the late 1970s was also found in other studies (Braschler, 1983; Chavas, 1983; Ferris, 1985). Except in 1981-82, however, the price response to income changes have steadily increased in the last five years.

These results imply that demand for beef is still responsive to income changes. It is observed, however, that the relative magnitude of the income flexibility in the 1980s were lower than those in the 1960s and early 1970s. This supports the hypothesis of a possible decline in the demand response to increases in income in the 1980s.

5.3.2 Pork Demand Model with Legendre Polynomial

To test for continous variation over time of the demand parameters for pork, the base model for pork demand is augmented by introducing varying degrees of Legendre polynomials on the own quantity, quantity of substitutes, and income variables. The F-test conducted indicate significant contribution of the polynomial on the own quantity and income variables.

The pork demand model with linear polynomial on both the per capita pork consumption and income variables is presented in Equation 5.30. The own-quantity flexibility estimated from this model show some variability over the entire period (see Figure 5.37). These estimates are all greater than unity. This implies that a one percent change in the quantity of pork available for consumption will lead to a more than proportionate change in pork prices. In broad terms, a flexible pork price is consistent with the inelastic demand for pork found in quantity dependent demand models.

The general pattern of the estimated own-quantity flexibility for pork is the same regardless of the degree of the polynomial introduced. Again this is a good characteristic of the results. The general pattern of variation could be associated with the hog production cycle. For example, the flexibility estimates tended to increase (in absolute values) between 1965 to 1971. During this period, hog prices are declining while quantities available for consumption per person increased. Thereafter, the own flexibility estimates declined to lower levels as pork quantity declined and pork prices increase. From 1975 to 1980, slaughtering increase and pork prices began to fall. This pattern of increased quantities available for

Equation 5.28

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	55.038745	15.333940	3.5893413	0.001
PKPC	-0.6260955	0.0891539	-7.0226343	0.000
P1QP	-0.0037521	0.0806934	-0.0464983	0.963
P2QP	-0.0722228	0.0199469	-3.6207617	0.001
BFPC	-0.2457646	0.0878952	-2.7961108	0.010
POULPC	-0.5357520	0.2095041	-2.5572385	0.017
DINC	0.0195845	0.0044416	4.4092992	0.000

R-squared	0.833152	Mean of dependent var	20.12544
Adjusted R-squared	0.791440	S.D. of dependent var	4.067107
S.E. of regression	1.857380	Sum of squared resid	82.79668
Durbin-Watson stat	1.714264	F-statistic	19.97394
Log likelihood	-59.21431		

Equation 5.29

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	44.388120	11.707579	3.7914005	0.001
PKPC	-0.7051900	0.0689554	-10.226762	0.000
P1QP	-0.1089986	0.0647574	-1.6831838	0.106
P2QP	-0.0823171	0.0150807	-5.4584549	0.000
P3QP	-0.0577581	0.0129306	-4.4667624	0.000
BFPC	-0.2625655	0.0658096	-3.9897721	0.001
POULPC	0.0471207	0.2038460	0.2311585	0.819
DINC	0.0158996	0.0034211	4.6474941	0.000

R-squared	0.910656	Mean of dependent var	20.12544
Adjusted R-squared	0.883464	S.D. of dependent var	4.067107
S.E. of regression	1.388401	Sum of squared resid	44.33612
Durbin-Watson stat	2.108006	F-statistic	33.49028
Log likelihood	-49.53319		

Equation 5.30

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	45.738633	13.207056	3.4631968	0.002
PKPC	-0.6884347	0.0866902	-7.9413195	0.000
P1QP	0.3395296	0.1171270	2.8988166	0.008
BFPC	-0.2054350	0.0707471	-2.9037928	0.008
POULPC	-0.5081512	0.1932412	-2.6296208	0.015
DINC	0.0230147	0.0043399	5.3030664	0.000
P1Y	-0.0090656	0.0020811	-4.3562105	0.000

R-squared	0.855928	Mean of dependent var	20.12544
Adjusted R-squared	0.819910	S.D. of dependent var	4.067107
S.E. of regression	1.725957	Sum of squared resid	71.49425
Durbin-Watson stat	1.824093	F-statistic	23.76395
Log likelihood	-56.93936		

Equation 5.31

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	48.271395	14.915010	3.2364306	0.004
PKPC	-0.6831863	0.0892674	-7.6532550	0.000
P1QP	0.2921695	0.1696638	1.7220495	0.098
P2QP	-0.0138677	0.0353395	-0.3924149	0.698
BFPC	-0.2224032	0.0840106	-2.6473235	0.014
POULPC	-0.5182258	0.1984080	-2.6119202	0.016
DINC	0.0226937	0.0044935	5.0502939	0.000
P1Y	-0.0077492	0.0039677	-1.9530415	0.063

R-squared	0.856886	Mean of dependent var	20.12544
Adjusted R-squared	0.813330	S.D. of dependent var	4.067107
S.E. of regression	1.757206	Sum of squared resid	71.01877
Durbin-Watson stat	1.845157	F-statistic	19.67308
Log likelihood	-56.83593		

Figure 5.35

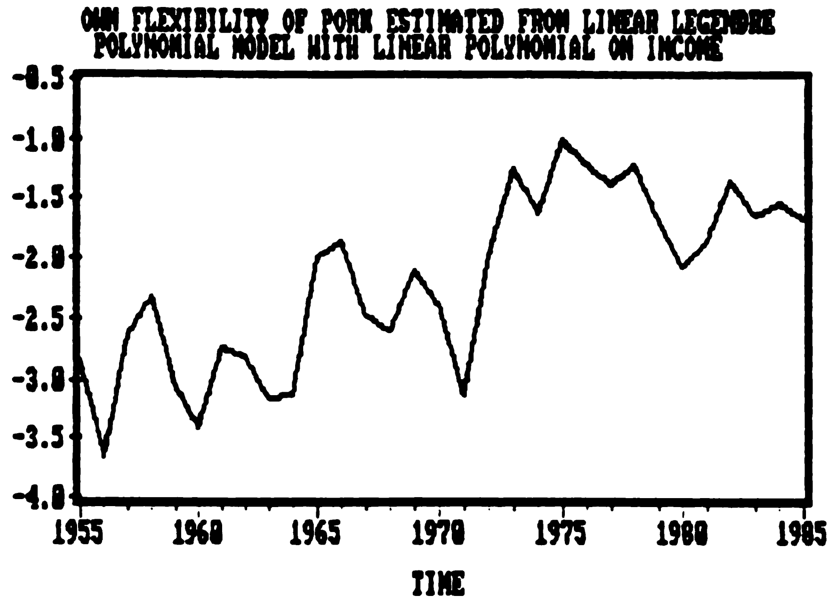


Figure 5.36

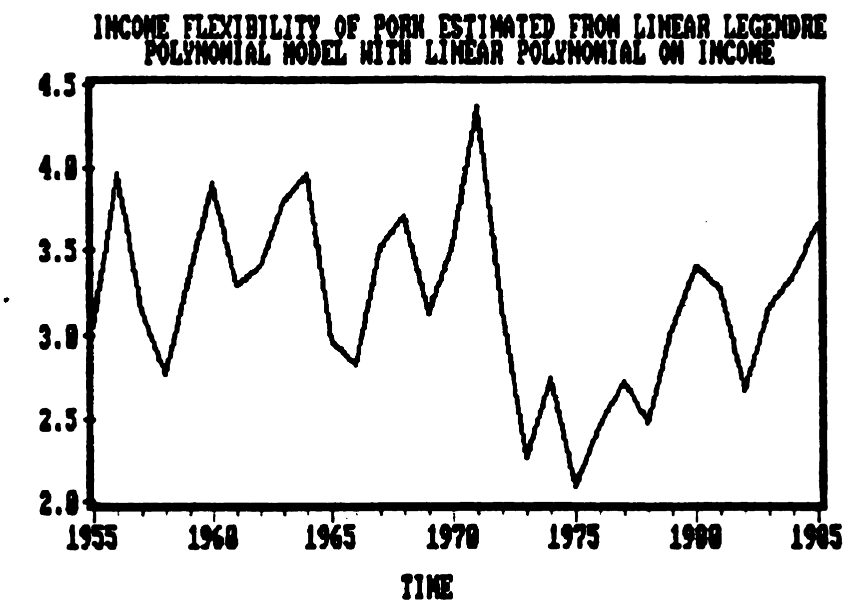


Figure 5.37

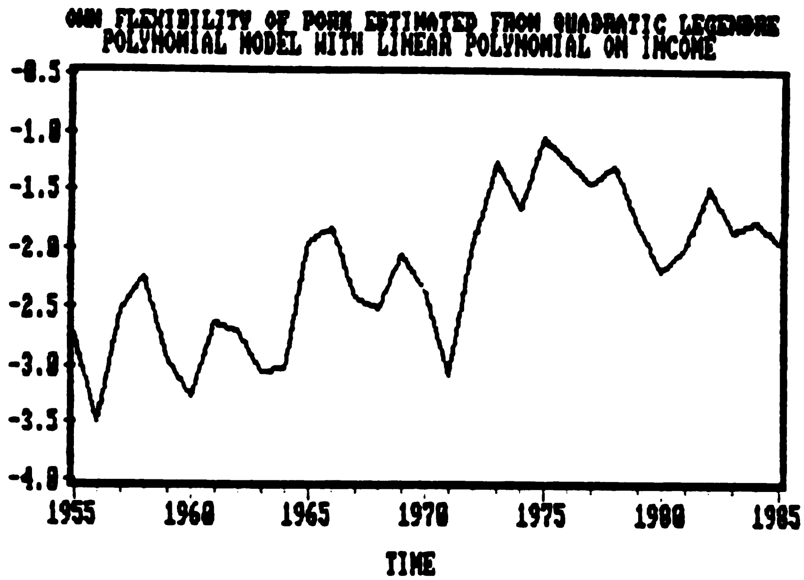
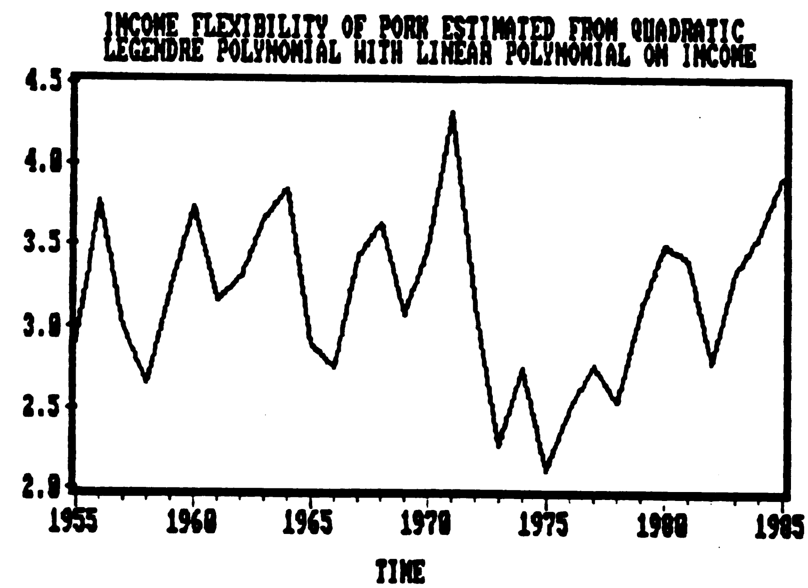


Figure 5.38



Equation 5.34

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	49.572497	17.317260	2.8626062	0.009
PKPC	-0.6151288	0.0914224	-6.7284275	0.000
P1QP	0.1145582	0.1861252	0.6154901	0.544
P2QP	-0.0302268	0.0627170	-0.4819554	0.634
BFPC	-0.2187766	0.0966774	-2.2629556	0.033
POULPC	-0.5099620	0.2148393	-2.3736899	0.026
P1QC	-0.1843767	0.2607386	-0.7071325	0.487
DINC	0.0201962	0.0045712	4.4181131	0.000

R-squared	0.836702	Mean of dependent var	20.12544
Adjusted R-squared	0.787003	S.D. of dependent var	4.067107
S.E. of regression	1.877034	Sum of squared resid	81.03492
Durbin-Watson stat	1.674005	F-statistic	16.83530
Log likelihood	-58.88094		

Equation 5.35

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	41.806572	12.368614	3.3800531	0.003
PKPC	-0.6833989	0.0662472	-10.315887	0.000
P1QP	-0.0738642	0.1373649	-0.5377224	0.596
P2QP	0.1855406	0.0626569	2.9612178	0.007
BFPC	-0.2649632	0.0691274	-3.8329671	0.001
POULPC	0.0523399	0.1908318	0.2742724	0.786
P1QC	-0.0141905	0.1879428	-0.0755046	0.940
P2QC	-0.3496844	0.0716118	-4.8830537	0.000
DINC	0.0163589	0.0033318	4.9098810	0.000

R-squared	0.921636	Mean of dependent var	20.12544
Adjusted R-squared	0.893140	S.D. of dependent var	4.067107
S.E. of regression	1.329517	Sum of squared resid	38.88753
Durbin-Watson stat	1.963176	F-statistic	32.34253
Log likelihood	-47.50073		

Equation 5.32

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	37.519970	14.595328	2.5706836	0.017
PKPC	-0.6671354	0.0763392	-8.7390892	0.000
P1QP	-0.1219338	0.1667201	-0.7313681	0.472
P2QP	-0.0615894	0.0521444	-1.1811310	0.250
BFPC	-0.2419288	0.0794624	-3.0445688	0.006
POULPC	-0.0144331	0.2257407	-0.0639364	0.950
P1QC	-0.0039428	0.2196862	-0.0179476	0.986
P2QC	-0.0624517	0.0178201	-3.5045699	0.002
DINC	0.0178038	0.0038060	4.6778801	0.000

R-squared	0.895206	Mean of dependent var	20.12544
Adjusted R-squared	0.857099	S.D. of dependent var	4.067107
S.E. of regression	1.537457	Sum of squared resid	52.00303
Durbin-Watson stat	1.988973	F-statistic	23.49197
Log likelihood	-52.00547		

Equation 5.33

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	66.928769	13.610837	4.9173148	0.000
PKPC	-0.6585725	0.0879080	-7.4916124	0.000
P1PK	-0.1731339	0.1616020	-1.0713595	0.296
BFPC	-0.3594283	0.0779063	-4.6135966	0.000
P1QB	0.0263708	0.0831489	0.3171511	0.754
POULPC	-0.3537566	0.1977638	-1.7887831	0.088
P1POUL	0.2405624	0.2111281	1.1394146	0.267
P2POUL	-0.1840423	0.0610157	-3.0163104	0.007
DINC	0.0169524	0.0038000	4.4611167	0.000
DV77ON	-2.4021230	1.5105241	-1.5902580	0.127

R-squared	0.902182	Mean of dependent var	20.12544
Adjusted R-squared	0.860260	S.D. of dependent var	4.067107
S.E. of regression	1.520356	Sum of squared resid	48.54111
Durbin-Watson stat	2.231285	F-statistic	21.52057
Log likelihood	-50.93766		

Equation 5.36

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	50.486878	16.701532	3.0228890	0.006
PKPC	-0.6800548	0.0789848	-8.6099422	0.000
BFPC	-0.2407857	0.0706323	-3.4090009	0.003
POULPC	-0.0479862	0.1703030	-0.2817694	0.781
P1QC	0.4759549	0.1741920	2.7323577	0.012
P2QC	-0.0860287	0.0431787	-1.9923852	0.059
DINC	0.0140851	0.0041738	3.3746646	0.003
P1Y	-0.0086530	0.0035479	-2.4389435	0.024
DV73ON	77.878221	42.542844	1.8305833	0.081
DVT73	-1.0179358	0.5853849	-1.7389169	0.097

R-squared	0.930527	Mean of dependent var	20.12544
Adjusted R-squared	0.900753	S.D. of dependent var	4.067107
S.E. of regression	1.281278	Sum of squared resid	34.47513
Durbin-Watson stat	2.518486	F-statistic	31.25305
Log likelihood	-45.63398		

Equation 5.37

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	47.392850	16.100817	2.9435060	0.008
PKPC	-0.7080155	0.0774236	-9.1446999	0.000
BFPC	-0.2342120	0.0677657	-3.4562019	0.002
POULPC	0.0740927	0.1782376	0.4156962	0.682
P1QC	0.3799660	0.1761488	2.1570742	0.043
P2QC	-0.0500385	0.0464643	-1.0769226	0.294
P3QC	-0.0308196	0.0181329	-1.6996543	0.105
DINC	0.0138526	0.0040002	3.4629714	0.002
P1Y	-0.0072179	0.0035016	-2.0612866	0.053
DV73ON	83.729206	40.894848	2.0474267	0.054
DVT73	-1.1167388	0.5637168	-1.9810282	0.062

R-squared	0.939296	Mean of dependent var	20.12544
Adjusted R-squared	0.908943	S.D. of dependent var	4.067107
S.E. of regression	1.227273	Sum of squared resid	30.12398
Durbin-Watson stat	2.661012	F-statistic	30.94655
Log likelihood	-43.54278		

Equation 5.38

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPORK

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	46.304588	17.122790	2.7042665	0.014
PKPC	-0.7226941	0.0840632	-8.5970351	0.000
BFPC	-0.2107483	0.0731945	-2.8792930	0.010
POULPC	-0.0037392	0.1853704	-0.0201717	0.984
P1QC	0.3790290	0.2036861	1.8608484	0.078
P2QC	-0.0060137	0.0713058	-0.0843363	0.934
DINC	0.0152745	0.0046267	3.3013713	0.004
P1Y	-0.0066255	0.0038443	-1.7234312	0.101
DV73ON	108.01646	48.138959	2.2438470	0.037
DVT73	-1.4493468	0.6682753	-2.1687872	0.043
DV80ON	85.157659	61.078517	1.3942326	0.179
DVT80	-1.0441868	0.7580480	-1.3774680	0.184

R-squared	0.937705	Mean of dependent var	20.12544
Adjusted R-squared	0.901639	S.D. of dependent var	4.067107
S.E. of regression	1.275548	Sum of squared resid	30.91345
Durbin-Watson stat	2.499419	F-statistic	25.99991
Log likelihood	-43.94376		

Equation 5.39

SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is PPORK
Convergence achieved after 7 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	57.055375	8.5821963	6.6481088	0.000
PKPC	-0.6911711	0.0576891	-11.980972	0.000
P1PK	0.0719286	0.1298762	0.5538242	0.587
BFPC	-0.4276840	0.0484328	-8.8304591	0.000
P1QB	0.3415339	0.0870337	3.9241561	0.001
POULPC	-0.3367322	0.1385780	-2.4299119	0.026
P1POUL	0.4084513	0.1630722	2.5047271	0.022
P2POUL	-0.0809983	0.0512209	-1.5813509	0.131
DINC	0.0243436	0.0024486	9.9416861	0.000
P1Y	-0.0216910	0.0046768	-4.6379713	0.000
DV77ON	-1.8458681	0.8073581	-2.2863064	0.035
AR(1)	-0.5106850	0.2101087	-2.4305753	0.026

R-squared	0.956518	Mean of dependent var	20.06686
Adjusted R-squared	0.929945	S.D. of dependent var	4.123312
S.E. of regression	1.091355	Sum of squared resid	21.43902
Durbin-Watson stat	2.616141	F-statistic	35.99634
Log likelihood	-37.52838		

Table 5.16 Own-Quantity Flexibility and Income Flexibility of Demand for Pork Estimated from Linear and Quadratic Legendre Polynomial Models, 1955-1985

	QUADRATIC	LINEAR		QUADRATIC	
YEAR	OWN-QUANTITY FLEXIBILITY	OWN-QUANTITY FLEXIBILITY	INCOME FLEXIBILITY	OWN-QUANTITY FLEXIBILITY	INCOME FLEXIBILITY
1955	-1.929	-2.856	3.045	-2.748	2.890
1956	-2.467	-3.643	3.968	-3.504	3.772
1957	-1.797	-2.643	3.151	-2.541	3.002
1958	-1.582	-2.314	2.771	-2.225	2.644
1959	-2.114	-3.071	3.372	-2.954	3.225
1960	-2.365	-3.404	3.906	-3.275	3.745
1961	-1.922	-2.737	3.289	-2.635	3.161
1962	-2.006	-2.819	3.419	-2.717	3.293
1963	-2.291	-3.171	3.787	-3.059	3.657
1964	-2.314	-3.148	3.972	-3.042	3.846
1965	-1.504	-2.007	2.976	-1.942	2.889
1966	-1.432	-1.870	2.819	-1.814	2.745
1967	-1.951	-2.486	3.523	-2.418	3.441
1968	-2.099	-2.604	3.717	-2.540	3.641
1969	-1.748	-2.106	3.118	-2.061	3.064
1970	-2.065	-2.409	3.539	-2.367	3.490
1971	-2.787	-3.142	4.369	-3.099	4.324
1972	-1.825	-1.981	3.144	-1.964	3.123
1973	-1.191	-1.242	2.264	-1.238	2.258
1974	-1.633	-1.630	2.737	-1.636	2.741
1975	-1.065	-1.016	2.099	-1.027	2.112
1976	-1.355	-1.230	2.463	-1.252	2.489
1977	-1.616	-1.392	2.728	-1.431	2.771
1978	-1.498	-1.220	2.482	-1.266	2.534
1979	-2.199	-1.689	3.033	-1.771	3.114
1980	-2.874	-2.073	3.404	-2.202	3.516
1981	-2.744	-1.852	3.279	-1.994	3.408
1982	-2.139	-1.346	2.666	-1.472	2.790
1983	-2.811	-1.642	3.168	-1.827	3.339
1984	-2.871	-1.551	3.355	-1.759	3.564
1985	-3.359	-1.669	3.658	-1.937	3.919

FLEXIBILITIES ARE CALCULATED AT THE MEANS.

Table 5.17 Own-Quantity Flexibility and Income Flexibility of Demand for Beef Estimated from Linear, Quadratic, and Cubic Legendre Polynomial Models, 1955-1985

	Linear	Quadratic	Cubic	CUBIC ON BFPC AND LINEAR ON DINC	
YEAR	OWN-QUANTITY FLEXIBILITY	OWN-QUANTITY FLEXIBILITY	OWN-QUANTITY FLEXIBILITY	OWN-QUANTITY FLEXIBILITY	INCOME FLEXIBILITY
1955	-0.471	-1.918	-1.736	-1.494	1.605
1956	-0.553	-2.085	-1.924	-1.672	1.726
1957	-0.559	-1.958	-1.838	-1.615	1.671
1958	-0.497	-1.621	-1.544	-1.374	1.452
1959	-0.521	-1.589	-1.533	-1.385	1.468
1960	-0.617	-1.767	-1.722	-1.581	1.579
1961	-0.716	-1.932	-1.899	-1.773	1.699
1962	-0.691	-1.765	-1.745	-1.658	1.589
1963	-0.888	-2.149	-2.135	-2.066	1.861
1964	-1.046	-2.411	-2.401	-2.368	2.071
1965	-0.985	-2.167	-2.162	-2.173	1.962
1966	-1.074	-2.262	-2.259	-2.313	2.018
1967	-1.185	-2.397	-2.392	-2.494	2.144
1968	-1.237	-2.411	-2.404	-2.551	2.141
1969	-1.239	-2.332	-2.323	-2.504	2.054
1970	-1.385	-2.525	-2.511	-2.747	2.199
1971	-1.341	-2.375	-2.539	-2.615	2.102
1972	-1.318	-2.274	-2.256	-2.531	2.013
1973	-1.095	-1.844	-1.829	-2.069	1.789
1974	-1.403	-2.314	-2.296	-2.617	2.042
1975	-1.503	-2.433	-2.419	-2.768	2.062
1976	-2.008	-3.196	-3.188	-3.653	2.511
1977	-2.045	-3.211	-3.217	-3.682	2.619
1978	-1.687	-2.617	-2.638	-3.006	2.217
1979	-1.323	-2.031	-2.065	-2.335	1.875
1980	-1.529	-2.331	-2.392	-2.677	2.055
1981	-1.816	-2.751	-2.858	-3.155	2.362
1982	-1.979	-2.985	-3.143	-3.413	2.441
1983	-2.161	-3.252	-3.477	-3.703	2.636
1984	-2.244	-3.374	-3.699	-3.822	2.737
1985	-2.561	-3.756	-3.876	-3.972	2.942

FLEXIBILITIES ARE CALCULATED AT THE MEANS.

consumption and falling prices is reflected in the upward trend in the own flexibility during the same period. The own-quantity flexibility estimates then fell between 1980 to 1982 primarily in response to reduced supplies available for consumption following herd liquidation and subsequently rising real prices. During the last three years, the flexibility estimates for pork remained relatively constant. The flexibility estimates for pork is in relatively lower levels during the 1970s and through the 1980s compared to the estimates in earlier periods.

Estimates of income flexibilities for pork (Figure 5.36 and 5.38) shows some year to year variation. A constant trend is evident from the beginning of the period until about 1973 when the income flexibility declined to lower levels. This decline is associated with the record prices in 1973 and the slight increase in income in the same year. Since the mid 1970s, the income flexibility estimates shows an upward trend, except in 1981 to 1982 when real disposable income per capita slightly declined resulting to a slight decline in the income flexibility. Much of the increase in the price response to income changes is due to relatively stable pork prices and the steadily rising income.

5.3.3 Broiler Demand Model with Legendre Polynomial

Continous variation in demand parameters for broilers is tested by introducing varying degree polynomials on the broiler per capita consumption, quantity of substitutes, and income variables. The linear polynomial specification on both the own quantity and income variables appears the best specification. This choice is based on the statistical properties of the model, particularly the resulting Durbin-Watson statistic and the general fit and relative magnitudes of the coefficients. It is observed that the higher degree legendre polynomial models for broilers have a Durbin Watson statistic indicating a tendency toward positive serial correlation. This phenomenon was not encountered in the beef and pork models.

The associated own-quantity flexibility estimates for broilers exhibit the same pattern regardless of the degree of the polynomials. The own-quantity flexibility estimates tended to increase (in absolute value) over the entire period of analysis. A discontinuity is apparent sometime in 1973 when the own-quantity flexibility declined in response to a slight decline in the quantity of broilers available for consumption and the subsequent record prices in 1973. After the decline in 1973, a continous upward trend in the own flexibility estimates remained during the late 1970s and through the 1980s.

Equation 5.40

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	55.570928	5.4914600	10.119518	0.000
POULPC	-1.0610717	0.1115154	-9.5150251	0.000
P1QC	0.1396009	0.0464442	3.0057761	0.006
BFPC	-0.1921163	0.0550466	-3.4900681	0.002
PKPC	-0.0732316	0.0644123	-1.1369196	0.266
DINC	0.0119930	0.0031783	3.7734445	0.001

R-squared	0.933736	Mean of dependent var	15.11533
Adjusted R-squared	0.920483	S.D. of dependent var	4.831722
S.E. of regression	1.362487	Sum of squared resid	46.40930
Durbin-Watson stat	1.804480	F-statistic	70.45538
Log likelihood	-50.24154		

Equation 5.41

SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	55.927127	5.5305528	10.112394	0.000
POULPC	-1.0020359	0.1304470	-7.6815531	0.000
P1QC	0.1346437	0.0469868	2.8655629	0.009
P2QC	-0.0122335	0.0138547	-0.8829837	0.386
BFPC	-0.1961505	0.0554792	-3.5355675	0.002
PKPC	-0.0810235	0.0652971	-1.2408437	0.227
DINC	0.0112073	0.0033140	3.3817664	0.002

R-squared	0.935821	Mean of dependent var	15.11533
Adjusted R-squared	0.919776	S.D. of dependent var	4.831722
S.E. of regression	1.368532	Sum of squared resid	44.94909
Durbin-Watson stat	1.721704	F-statistic	58.32529
Log likelihood	-49.74601		

Figure 5.39

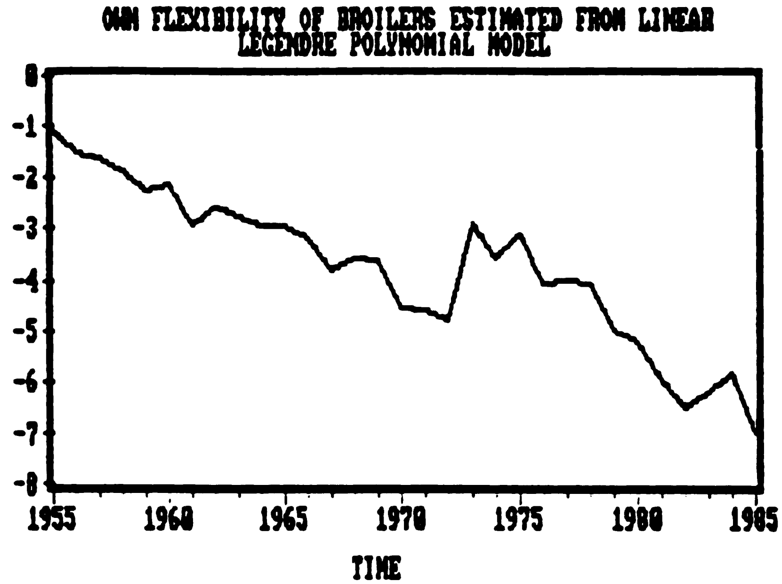
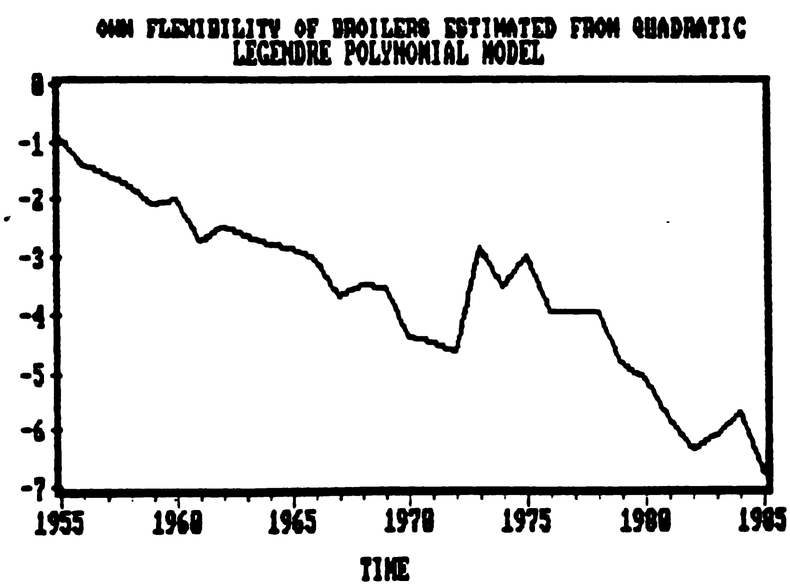


Figure 5.40



Equation 5.42

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	35.442659	12.671059	2.7971348	0.010
POULPC	-0.7961114	0.1702866	-4.6751254	0.000
P1QC	0.0010808	0.0875099	0.0123504	0.990
P2QC	0.0675345	0.0379500	1.7795661	0.088
P3QC	-0.0320037	0.0173055	-1.8493380	0.077
BFPC	-0.1328881	0.0639282	-2.0787076	0.049
PKPC	-0.0669035	0.0630364	-1.0613469	0.300
DINC	0.0126094	0.0032702	3.8558524	0.001

R-squared	0.943588	Mean of dependent var	15.11533
Adjusted R-squared	0.926419	S.D. of dependent var	4.831722
S.E. of regression	1.310644	Sum of squared resid	39.50910
Durbin-Watson stat	1.694360	F-statistic	54.95918
Log likelihood	-47.74653		

Equation 5.43

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	37.693857	5.9564856	6.3282041	0.000
POULPC	-0.8647937	0.0974441	-8.8747662	0.000
P1QC	0.5429892	0.1011893	5.3660747	0.000
BFPC	-0.1813518	0.0424636	-4.2707584	0.000
PKPC	-0.1634382	0.0539284	-3.0306502	0.006
DINC	0.0166067	0.0026762	6.2053799	0.000
P1Y	-0.0096019	0.0022532	-4.2615214	0.000

R-squared	0.962279	Mean of dependent var	15.11533
Adjusted R-squared	0.952849	S.D. of dependent var	4.831722
S.E. of regression	1.049178	Sum of squared resid	26.41860
Durbin-Watson stat	2.192228	F-statistic	102.0414
Log likelihood	-41.50835		

Figure 5.41

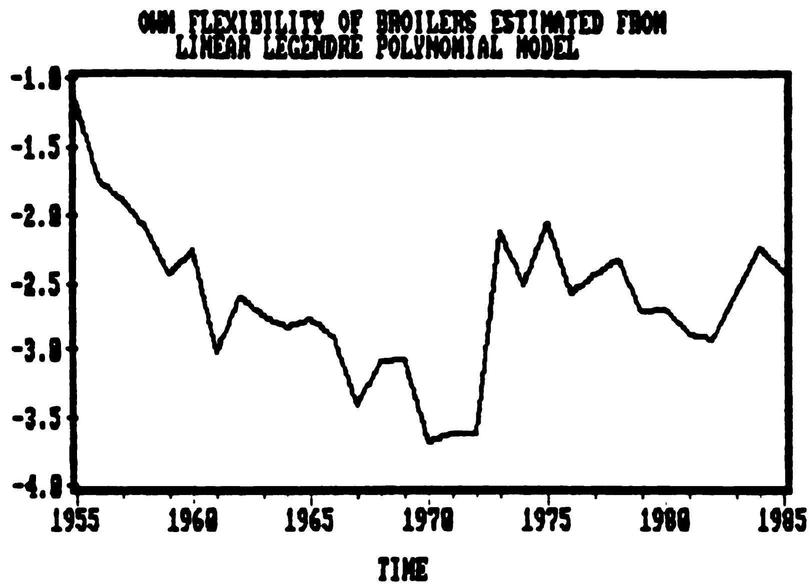
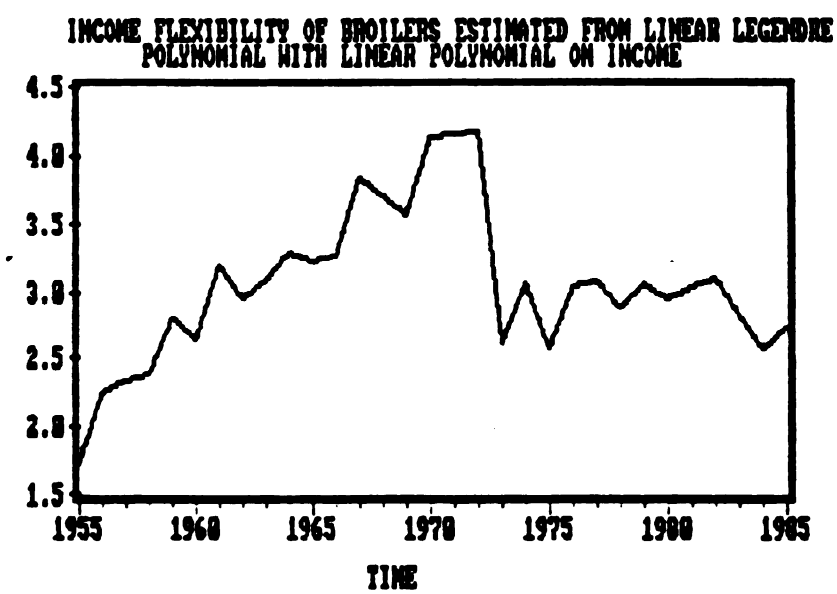


Figure 5.42



Equation 5.44
SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	44.294775	8.4255545	5.2571941	0.000
POULPC	-0.8859170	0.0988811	-8.9594188	0.000
P1QC	0.6496148	0.1396280	4.6524684	0.000
P2QC	-0.0287300	0.0260517	-1.1028063	0.282
BFPC	-0.2096179	0.0494370	-4.2401058	0.000
PKPC	-0.1867018	0.0576828	-3.2366968	0.004
DINC	0.0160788	0.0027069	5.9399615	0.000
P1Y	-0.0108685	0.0025200	-4.3128331	0.000

R-squared	0.964173	Mean of dependent var	15.11533
Adjusted R-squared	0.953270	S.D. of dependent var	4.831722
S.E. of regression	1.044485	Sum of squared resid	25.09181
Durbin-Watson stat	2.411697	F-statistic	88.42562
Log likelihood	-40.70969		

Equation 5.45
SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	32.412370	9.2877055	3.4898146	0.002
POULPC	-0.6807427	0.1270180	-5.3594190	0.000
P1QC	0.5483235	0.1354103	4.0493483	0.001
P2QC	0.0136247	0.0301342	0.4521341	0.656
P3QC	-0.0292329	0.0126669	-2.3078094	0.031
BFPC	-0.1757794	0.0476665	-3.6876953	0.001
PKPC	-0.1861745	0.0529208	-3.5179816	0.002
DINC	0.0157545	0.0024874	6.3338161	0.000
P1Y	-0.0106137	0.0023146	-4.5855201	0.000

R-squared	0.971156	Mean of dependent var	15.11533
Adjusted R-squared	0.960667	S.D. of dependent var	4.831722
S.E. of regression	0.958248	Sum of squared resid	20.20128
Durbin-Watson stat	2.319192	F-statistic	92.59086
Log likelihood	-37.34935		

Figure 5.43

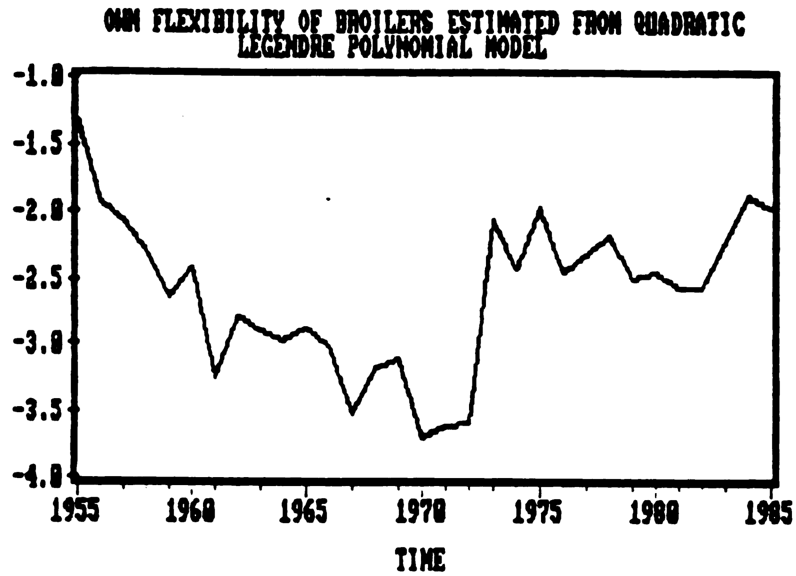


Figure 5.44

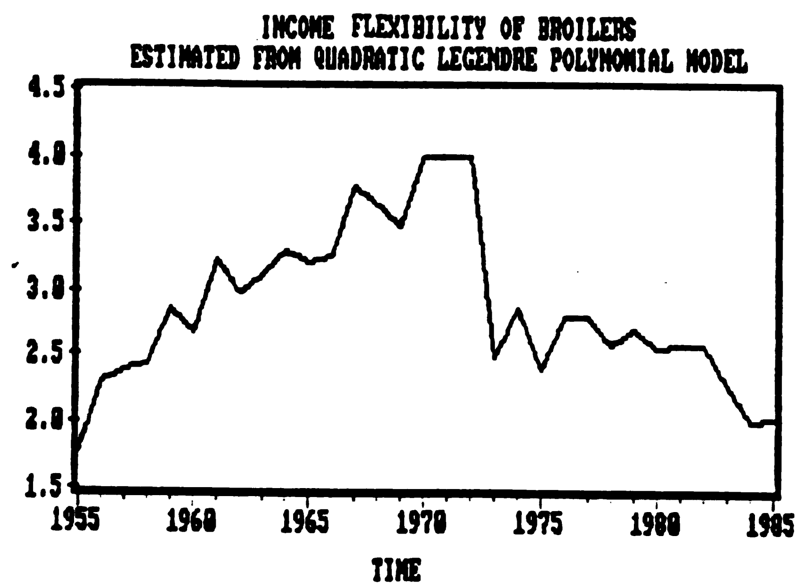


Figure 5.45

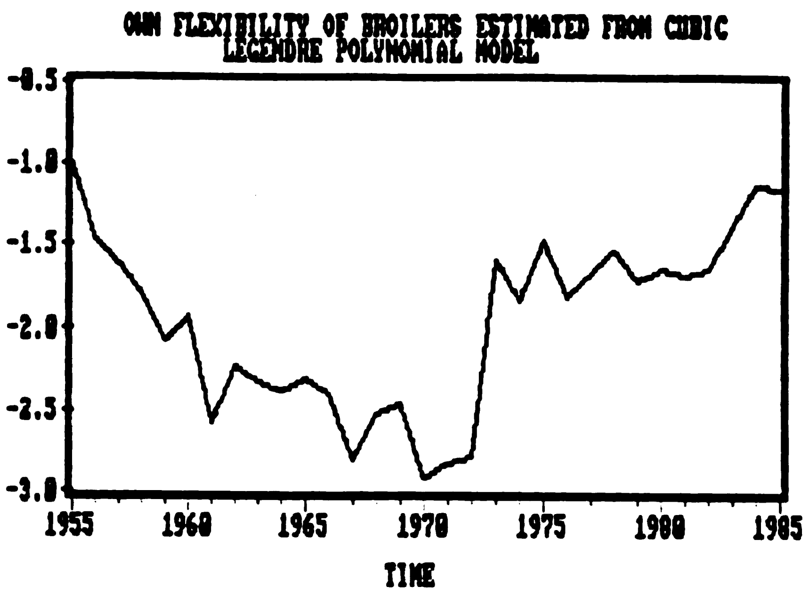
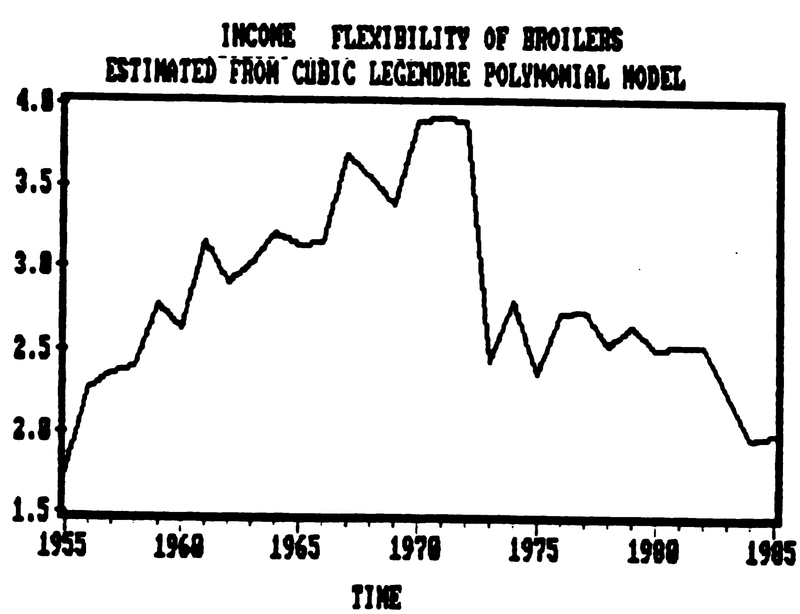


Figure 5.46



Equation 5.46
SMPL 1956 - 1985
30 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	42.832439	8.4181169	5.0881260	0.000
POULPC	-0.7500524	0.1331284	-5.6340515	0.000
P1POUL	0.4034491	0.1461901	2.7597566	0.012
BFPC	-0.2284022	0.0490387	-4.6575910	0.000
P1QB	0.0619824	0.0797234	0.7774676	0.446
PKPC	-0.1720619	0.0532616	-3.2305043	0.004
P1PK	-0.0009658	0.0789233	-0.0122371	0.990
DINC	0.0149713	0.0027074	5.5297452	0.000
P1Y	-0.0090175	0.0048084	-1.8753697	0.075
DV77ON	-0.9871041	0.9673410	-1.0204303	0.320

R-squared	0.956908	Mean of dependent var	14.57179
Adjusted R-squared	0.937517	S.D. of dependent var	3.830970
S.E. of regression	0.957613	Sum of squared resid	18.34046
Durbin-Watson stat	2.298371	F-statistic	49.34727
Log likelihood	-35.18684		

Equation 5.47
SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	36.810086	9.4080861	3.9126009	0.001
POULPC	-0.6953465	0.1239671	-5.6091196	0.000
P1POUL	0.4780806	0.1394998	3.4271059	0.003
P2POUL	0.0119967	0.0327994	0.3657590	0.718
P3POUL	-0.0404420	0.0153433	-2.6358064	0.016
BFPC	-0.1711699	0.0538738	-3.1772401	0.005
P1QB	-0.0721226	0.1099385	-0.6560269	0.519
PKPC	-0.1732366	0.0541349	-3.2000902	0.004
DINC	0.0140059	0.0028948	4.8383786	0.000
P1Y	-0.0058901	0.0054699	-1.0768299	0.294
DV77ON	-1.7742311	0.9958451	-1.7816336	0.090

R-squared	0.975169	Mean of dependent var	15.11533
Adjusted R-squared	0.962753	S.D. of dependent var	4.831722
S.E. of regression	0.932495	Sum of squared resid	17.39092
Durbin-Watson stat	2.341165	F-statistic	78.54389
Log likelihood	-35.02749		

Equation 5.48

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is CHP

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	41.073683	9.2539105	4.4385217	0.000
POULPC	-0.8495109	0.1393767	-6.0950698	0.000
P1POUL	0.6213346	0.1251485	4.9647784	0.000
BFPC	-0.2343023	0.0540494	-4.3349643	0.000
P1QB	0.1106309	0.0849958	1.3016033	0.207
PKPC	-0.1561360	0.0583071	-2.6778201	0.014
P1PK	-0.0147643	0.0868618	-0.1699750	0.867
DINC	0.0171080	0.0028161	6.0749520	0.000
P1Y	-0.0142785	0.0047027	-3.0361988	0.006
DV77ON	-0.8367400	1.0652544	-0.7854837	0.441

R-squared	0.966511	Mean of dependent var	15.11533
Adjusted R-squared	0.952158	S.D. of dependent var	4.831722
S.E. of regression	1.056834	Sum of squared resid	23.45484
Durbin-Watson stat	2.344333	F-statistic	67.34046
Log likelihood	-39.66399		

To test for continous variation in the price response to income changes, the models are augmented by a linear polynomial on the income variable. The latter is significant based on the F-test at the .05 level. The model with linear polynomial on both the own quantity and income variables has the best statistical properties among the broiler polynomial models. It is observed that the pattern of the own-quantity flexibility estimates after allowing the income coefficient to vary over time remained the same in all the augmented models. However, the relative magnitude of the flexibility estimates from the augmented models seem to be more reasonable compared with those estimated from the models with constant parameters on income variable.

Slight year to year variation in the own quantity flexibility of demand for broilers is evident for the entire period of analysis. Similar to the estimates from the three polynomial models, the own quantity flexibility estimated while allowing the coefficient on income to vary over time exhibit an upward trend from the beginning of the period through the early 1970s. A discontinuity occurs in 1973 when the own flexibility declined by about forty percent from its 1972 level. This decline in own flexibility reflects the slight decline in the available quantities of broilers and the record prices in 1973. The flexibility in the mid 1970s through early 1980s trended upward slowly until 1984 when a slight decline in the estimate occured.

5.5 Summary and Conclusions

In this chapter, recursive least squares and residual analysis were applied to estimate and test parameter change in the U.S. farm level demand for beef, pork, broiler, and turkey. Recursive least squares facilitates the identification of the timing of structural change and measurement of changes in demand parameters. Standardized recursive residuals were estimated and used in performing an exploratory analysis to look for patterns indicative of possible structural breaks in demand for meat. The recursive parameter estimates are used as a descriptive devise in determining the effects of individual observations in a recursive updating procedure. Changes in parameters are indicated by trends and discontinuities in the recursive residuals and a systematic tendency to overpredict or underpredict.

The results of the recursive least squares and recursive residual analysis strongly reject the null hypothesis of constant parameters in the inverse demand for beef, pork, and broilers. In particular, the parameters of the linear inverse demand models for beef, pork, and broilers show signs of instability. Forward recursions indicate a tendency to systematically overpredict prices of the three commodities starting in 1976-1977. This period is identified as an important structural break in the demand for the three commodities. No significant parameter instability was found in the inverse demand for turkey.

In the case of the beef price model, the most striking feature is the declining and increasing trend (in absolute value) in the estimates of coefficients on the beef per capita consumption and poultry per capita consumption, respectively. The recursive estimates of the coefficient on real per capita disposable income appear to have slightly declined over the period. A discontinuity is evident in beef demand starting in 1977 when the estimated standardized recursive residuals increased (in absolute value) to -8.09 from 0.595 in 1976. The standardized recursive residuals from 1977 to 1985 are more than twice the absolute value of the largest residual in the 1955-1976 period.

Recursive parameter estimates of the pork price model also show signs of instability. The absolute value of the coefficient on pork per capita consumption (PKPC) showed an increasing trend during the 1965-1971 period. A discontinuity is apparent in 1971 when the coefficient on PKPC declined in absolute value until 1978. From the forward one-step recursive residuals, there is a tendency to overpredict pork prices starting in 1971 reaching the two largest overpredictions in 1977 and 1984.

The recursive residuals estimated from the broiler demand model indicate a significant structural break starting in 1976. The information on the timing of discontinuity in the demand parameters indicated by the standardized recursive residuals is used in respecifying the demand models to explicitly account for the changes in the demand parameters for the three commodities.

The first specific form of parameter variation tested is a gradual structural shift in demand due to the hypothesized continous changes in tastes and health concerns. This is carried out by introducing trend variables. One trend variable representing the trend from 1955-76 and another to represent the turning point in the trend from 1977 to 1985. Since the model is linear in the variables, the coefficient on the time trend represent the rate of shift in demand in terms of annual prices, given quantities and income.

Estimated own-quantity flexibility of demand for pork increased (in absolute value) from -1.8768 in 1955-85 to-2.6041 in 1970-85. The cross flexibility of pork demand with respect to beef and poultry both increased in 1970-85.

The estimated own-quantity flexibility of demand for beef increased in absolute value in the second period (1970-85). A significantly positive income flexibility was estimated for the period 1955-85. This estimate is found to be slightly higher compared to the income flexibility of beef demand for the period 1970-85. The cross flexibility of beef demand with respect to broilers increased significantly in the second period. This result supports the hypothesis of increasing substitutability of poultry with beef in the 1970s and through the 1980s.

In contrast with beef, the estimated own-quantity flexibility of demand for pork is very close in the two periods. However, the cross flexibility of pork demand with respect to poultry and the income flexibility both increased in the second period.

In the case of broiler,the own quantity flexibility and cross flexibility with respect to beef and pork both increased in the second period. The price of broilers has become more responsive to income changes in the period 1970-85.

The results from the demand models with trend variables indicate an absence of a significant trend in the demand for beef, pork and broilers before 1976. A significant downward trend was found in the demand for beef starting in 1977. Gradual continous variation in the inverse demand parameter was tested by introducing Legendre polynomials. Linear, quadratic, and cubic Legendre polynomials specification for the own quantity, quantity of substitutes and complements, and income variables were tested.

In general, the results imply that the maintained hypothesis of constant parameters of inverse demand for beef, pork, and broiler, can be rejected at the 0.01 level based on F-tests. Flexibility estimates indicate that beef prices are becoming more sensitive to changes in beef supplies over time. The own flexibility of steer price slightly trended upward in absolute value during the 1955-1985 period. Larger fluctuations in the own quantity flexibility starting in mid 1970s is indicative of a structural break in beef demand staring mid 1970s. The analysis of price response to changes in quantities indicate that steer prices is slightly more response to supply changes than are hog prices. Steer price is becoming less sensitive to income changes. The relative magnitude of the income flexibility in the 1980s were slightly lower than those in 1960s and early 1970s. Hog prices are becoming less sensitive to changes in pork supplies over time. the own-quantity flexibility estimates for hogs are relatively in lower absolute values during the 1970s and in 1980s compared to estimates in earlier periods. A discontinuity is apparent in the hog price response to income changes during the mid 1970s. Income flexibility for hogs exhibited a constant trend from 1955 until 1983. Starting in mid 1970s income flexibility for hog trended upward.

The results indicate that broiler prices have become more responsive to changes in broiler supplies over time. The own quantity flexibility estimates tended to increase in absolute value over the 1955-72 period. A discontinuity is evident in 1973 when the own quantity flexibility of broilers declined in absolute value. After the decline in

1973, estimates continued to exhibit an upward trend in absolute value.

A structural break is apparent in the broiler price response to income changes. Estimates of income flexibility for broilers exhibit an upward trend during the 1955-72 period. The estimate significantly decline from about 4.1 in 1972 to 2.5 in 1973. It then remained in the 2.5 to 3.0 range during the rest of the period.

In general, the preceding analysis provides additional evidence that a structural break has occured in the farm level demand for beef, pork, and broilers. Based on the analysis of recursive parameters and recursive residuals for 1955-85, the change began in 1976-1977 and continued into 1980s. The structural change resulted in higher own quantity flexibilities for beef, pork, and broilers. Also, the results imply that broiler is becoming a stronger substitute for beef and pork.

However, the causes of such change are not investigated in this study. The study only allows the approximation of the effects of structural change on the magnitudes of price and income response parameters. These results are useful in forecasting the growth prospects of the U.S. livestock and poultry sector.

CHAPTER 6

INCORPORATING STRUCTURAL CHANGE IN U.S. PORK PRODUCTION IN THE SPECIFICATION OF THE U.S. HOG SUPPLY RESPONSE MODEL

6.1 Structural Changes in U.S. Pork Production

Like the rest of the U.S. agricultural sector, pork production has become more concentrated on larger and specialized farms. Varn Arsdall and Nelson (1984)[1] indicated that between 1950 and 1980, there was about 80 percent decline in the number of U.S. hog farmers. Average sales per farm increased from 31 in 1950 to almost 200 head in 1980. Moreover, they indicated that in 1980, about 40 percent of all hogs were produced in farms selling 1,000 or more head, which constituted about 3 percent of the total U.S. hog farms. In contrast, only 7 percent of total hog marketings in 1964 were from such large operations.

Despite the sharp decline in the number of hog farmers, U.S. hog production remained at relatively stable levels during the last 30 years. However, national average per capita consumption of pork trended downward during this period. Varn Arsdall and Nelson reported that the drop in pork per capita consumption is largely due to the decline in the use of lard. Pork represented about 37 percent of U.S. red meat consumption in 1985, down from about half in 1955.

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[1] Van Arsdall, R.N., and K.E. Nelson, (1984).

The shift toward larger and specialized farms brought about some important changes in the structure of hog supply response. This section provides a summary of some important aspects of the structural changes that have occurred in U.S. hog production. These changes are considered in constructing the hog supply response model and in determining the likely future trends in hog production and supply. The summary is based on a number of previous studies on the structural characteristics of the hog industry (Van Arsdall and Nelson, 1984; Hayenga,et.al., 1985, and USDA statistical reports.

6.1.1 Trends in Pork Production

During the early 1950s, pork constituted more than half of the total U.S. red meat production, averaging at about 13 billion pounds in carcass weight. Although production of hogs fluctuated cyclically, pork output in the late 1970s stayed at a relatively the same range of 11 to 15 billion pounds in carcass weight. In the early 1980s, pork was a third (37 percent) of the total red meat supply.

Hog inventory data indicate between 1978 and 1980, the most rapid expansion occurred in the larger hog operations. It is observed that during profitable periods, expansion occurs across all sizes of hog farms. On the other hand, small farms reduce their production or drop out during bad times while larger farms tend to stabilize their production.

During the mid 1970s, hog production and pork per capita consumption were at relatively low levels, while beef cattle production reached a record levels. Per capita disappearance of pork in carcass weight dropped from 75-85 pounds range during the 1950s to about 60-70 pounds in the last 10 years. The decline is partially the result of a reduction in lard consumption which averaged about 14 pounds per capita during the 1950s and about 2 pounds in the late 1970s. Market analysts have considered this to be a reflection of a shift in consumers preferences.

6.1.2 Technical Change and Trends in Production Efficiency

New technologies that have been adopted by hog producers altered the competitive situation in hog production. Van Arsdall (1984) indicated that technological advancements in nutrition and control of diseases of hogs eliminated the necessity of having a large land base in hog production. Also, technical advancements in housing and materials handling equipment permitted the continuous year round production and increases in production per unit of labor. Government policies on research and taxation facilitated the adoption of capital intensive technologies and large size hog enterprises. These technical advances resulted in more intensive use of land for crop production while hog raising become less dependent on land resources. Hog production has become a year round activity with capital intensive systems common in large scale operation.

The trends in physical relationships between major inputs used and a unit of output has been indicative of the performance of the hog industry. Since future shifts in hog production will be determined in part by future changes in these physical and biological factors, it is useful to determine the probable future changes of these variables.

6.1.3 Trend in Pigs Per Litter

The number of pigs weaned per litter is indicative of the genetic quality of the breeding stock and the quality of attention and care given by the producer. Average pigs per litter increased from about 6.9 in 1955 to about 7.6 in 1985. Litter size has been trending upward except during the period 1968-75, where litter size slightly declined from about 7.3 to about 7.0 pigs (Figure 6.2). Since gilts generally provides a lower number of pigs per litter than mature sows, a lower replacement rate of females results to a higher average litter size.

6.1.4 Trends in Average Dressed Weights of Hogs

Average dressed weight has been trending upward over the last 30 year period (Figure 6.3). From a level of 136 pounds in 1955 to an average of 174 pounds in 1985. Market slaughter weight is largely determined by the hog-corn price ratio and the quality of the stock. During periods when the hog-corn price ratio is low, hog producers usually market slaughter hogs at lower weights.

6.1.5 Trends in Death Losses As Percent of Total Pig Crop

Death losses as percent of total pig crop were a little over 10 percent during the mid 1950s. A downward trend in percent death loss occurred from 1960 to 1970 (Figure 6.4). From a little above 6 percent in 1970, a slight increase to about 8 percent occurred in 1974. Since 1975, death loss has been fluctuating at a range of 7 to 8 percent of the total pig crop. The trend toward confined housing in hog production has enabled the producer to have greater control of the environment and prevent diseases.

Figure 6.1

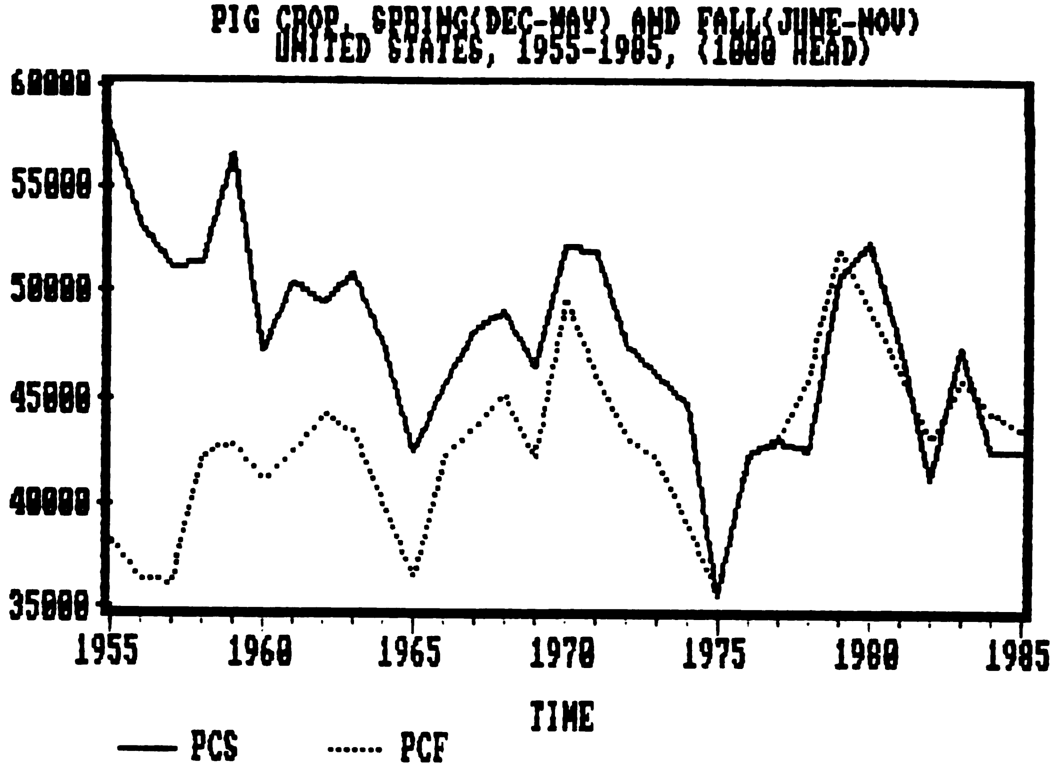


Figure 6.2

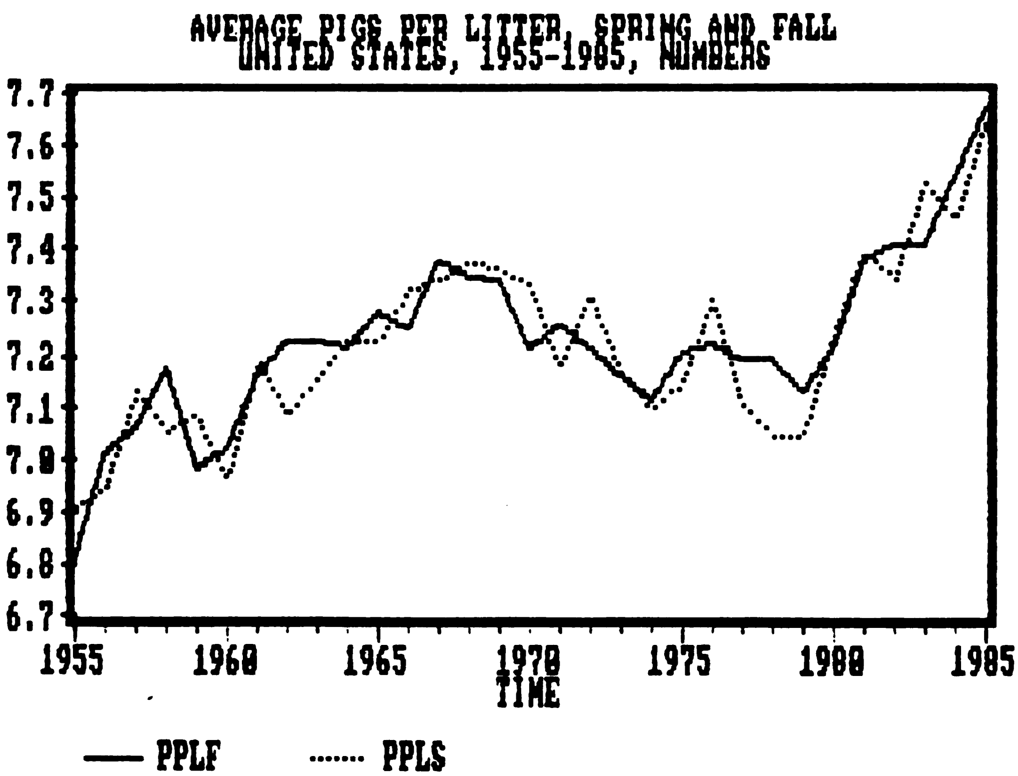


Figure 6.3

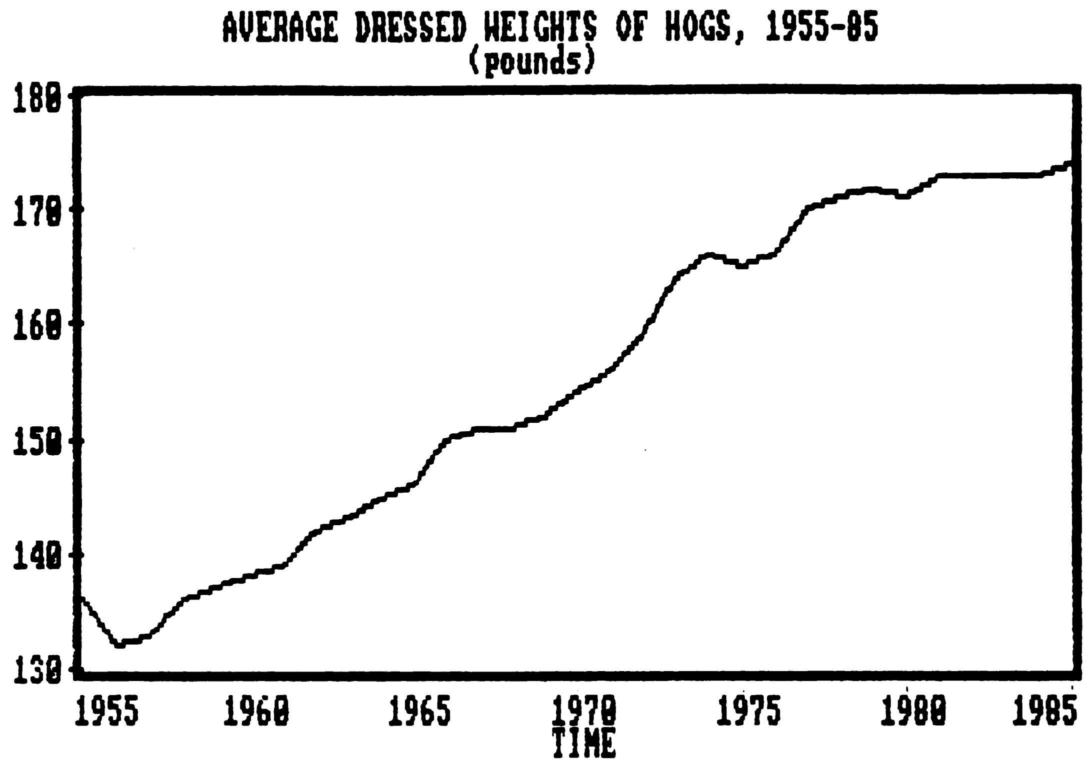
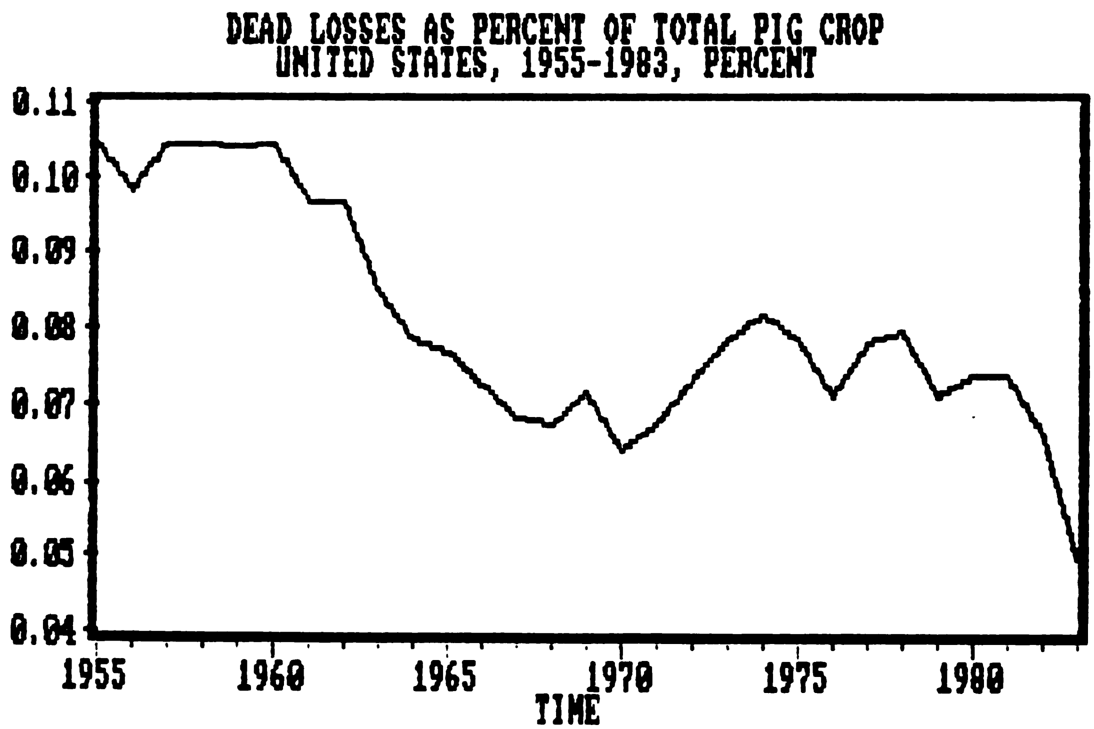


Figure 6.4



6.2 Physical Relationships in Modeling Pork Supply

Johnson, et.al., (1983) hypothesized that biological relationships such as birth, culling, replacement, maturing, and marketing rates can be used as conditioning mechanisms for modeling livestock supply response. Johnson and MacAulay (1980) and later Okyere (1982) used the physical accounting relationships in the form of stock-flow relationship to restrict a beef supply model. Chavas and Johnson (1982) modeled the sequence of production stages in the U.S. broiler and turkey production, giving particular emphasis on the biological and physical relationships that characterize the structure of supply response.

In specifying a farm level pork supply response model Johnson, et.al., (1983) incorporated information on the technical and biological factors in pork production. Pork supply response was hypothesized to be mainly a function of long-term biological, technical and institutional ratios and trends. Any deviation from the long-term trend was explained by changes in relevant economic factors, such as output and input prices. Biological relationships are introduced as restrictions in the hog supply response model. These restrictions enter as physical accounting relationships.

Following the notation of Johnson, et.al., the biological relationships between stock and flows are defined as follows:

$$(6.1) \quad CI_t + S_t = CI_{t-1} + IN_t$$

where CI_t is the closing inventory, S_t is the outflow or slaughter and IN_t is the inflow from one stage to another. This identity is applied to determine the flow of gilts that become sows, baby pigs that become feeder pigs, and feeder pigs that become slaughter hogs. Specifically, the following identities are considered:

$$(6.2) \quad BHI_t + SS_t = BHI_{t-1} + ABH_t$$

$$(6.3) \quad PC_t + ABH_t = PC_{t-1} + FP_t$$

$$(6.4) \quad FP_t + BGS_t = FP_{t-1} + FSH_t$$

where BHI is the closing inventory of the breeding herd, SS is the outflow or commercial slaughter of sows, ABH is the flow of gilts becoming sows, PC is the closing inventory of the pig crop, FP is the flow of the pig crop to feeder pigs, BGS is the commercial slaughter of barrows and gilts and FSH is the flow of feeder pigs that become slaughter hogs. The number of gilts becoming sows, ABH, is estimated using 6.2.

ABH is then substituted in 6.3 to calculate the number of pigs that become feeder pigs. The latter is then used to calculate the number of feeder pigs that become slaughter hogs using 6.4. These physical accounting relations allows a systematic determination of the pork production process and a more coherent analysis of supply response.

The next step in the analysis is the calculation of ratios between the flow and stock variables estimated using the identities. For instance, the ratio between gilts becoming sows (ABH) and the baby pigs becoming feeder pigs are estimated. The proportion of slaughter hogs to the total breeding herd and the ratio between the pig crop and the breeding herd with appropriate lags are also calculated. These ratios together with the identities constitute the physical restrictions in the pork supply response model.

The trends in these ratios are indicative of the impacts of some of the aspects of structural change occurring in U.S. hog production. In particular, it is observed that the ratio of sow slaughter to the lagged breeding herd has been trending downward overtime. Johnson, et.al., indicated that this could be explained by the improvement in technology in hog production. They hypothesized that control of diseases and improvement in management technology in hog production may have allowed the producers to farrow more litters per sow and hence not to replace sows as often. Furthermore, the ratio of the pig crop to the breeding herd has stabilized in recent years. This stability is explained by the movement of the hog industry towards more large scale operations and more confined hog production. This structural change has tended to give hog producers an increasing ability to control the environment surrounding hog production and lessen the variability in pork output.

Johnson,et.al., (1983) used these biological trends as explicit restrictions in their hog model by estimating a trend equation with the following form

$$(6.5)\quad R_i = a_i + b_i\, t\, DV + c_i\, DV \quad (i = 1,2,3,4)$$

where R_i is a quarterly biological ratio, t is a time variable, DV is a dummy variable which equal one prior to 1975 and zero after and including 1975. a, b, and c are parameters to be estimated.

Sow slaughter was then specified as primarily a function of the long term ratios and trends, price of barrows and gilts, price of inputs and cost of money. Specifically sow slaughter is specified as follows

$$(6.6)\quad SS = f(RATIOS, LAG, OP, IP, I)$$

where SS represents sow slaughter, RATIOS is the long term biological ratio, OP is the output price, IP is the input price, I is the cost of money, and LAG is the relevant lagged inventory variable.

In this specification, the level of supply is primarily determined by the average biological ratios. Deviations of output from the long term average trend is explained by changes in economic variables such as input and output prices and other relevant costs.

Additions to the breeding herd was specified in the same fashion as sow slaughter. Results of the model validation conducted by Johnson et.al., indicated that the general tracking performance is improved by using the trends as restrictions. However, inaccuracies in the simulation results of the additions to the breeding herd variable were encountered. It is noted that this problem stemmed from the potential errors in the data for breeding herd inventories. Unfortunately, their model is specified such that any inaccuracies in the inventory data are carried over to the barrow and gilt slaughter variable.

The general method reviewed above offers potential usefulness and relevance in attempts to consider structural change in livestock production in specifying a livestock supply response model. For the present study, long term biological trends and ratios constraining hog supply is used. The analytical framework is, however somewhat extended and modified by considering other aspects of structural change in hog production that has affected the

trend in the biological relationships. Also, due to the inaccuracies in the published data on hog breeding herd inventory, the model specification is modified by first estimating sow farrowings equation instead of the breeding herd equation. A third modification involves the specification of the biological ratios. Johnson, et. al., used a dummy variable to capture the shift in the biological relationships. Specifically, their specification is such that the biological ratios are conditioned by a linear time trend prior to 1975 and are constants after 1975.
Plots of the biological ratios over time used in this study indicate changes after 1975. Cubic spline functions are used in estimating these changes.

6.3 Structure of the Pork Supply Model

The hog supply model is composed of 9 structural equations and 14 definitional equations. The equations are specified as follows

(6.3.1) SOWFST = F(BIOLOGICAL TREND, PPORK(L), CORNP(L), SOYMP(L))

(6.3.2) SOWFFT = F(BIOLOGICAL TREND, PPORK(L), CORNP(L), SOYMP(L))

(6.3.3) PPLS = F(BIOLOGICAL TREND)

(6.3.4) PPLF = F(BIOLOGICAL TREND)

(6.3.5) PCS = SOWFST * PPLS

(6.3.6) PCF = SOWFFT * PPLF

(6.3.7) TPC = PCS + PCF

(6.3.8) PCSS = (1 - DLPC) * PCS

(6.3.9) PCSF = (1 - DLPC) * PCF

(6.3.10) GSS = 0.5 * PCSS

(6.3.11) GSF = 0.5 * PCSF

(6.3.12) PGRS = F(BIOLOGICAL TREND, PPORK(L), CORNP(L))

(6.3.13) PGRF = F(BIOLOGICAL TREND, PPORK(L), CORNP(L))

(6.3.14) GRTS = PGRS * GSF(-1)

(6.3.15) GRTF = PGRF * GSS

(6.3.16) SLBGS = PCSF(-1) - GRTS

(6.3.17) SLBGF = PCSS - GRTF

(6.3.18) SSS = F(BIOLOGICAL TREND, PPORK(L), CORNP(L), SOYMP(L))

(6.3.19) SSF = F(BIOLOGICAL TREND, PPORK(L), CORNP(L), SOYMP(L))

(6.3.20) ADWHG = F(BIOLOGICAL TREND, PPORK(L), CORNP(L))

(6.3.21) TSLHG = SLBGS + SLBGF + SSS + SSF

(6.3.22) PORKQT = (TSLHG * ADWHG)/1000

where

SOWFST = Sow farrowings in spring, December(t-1)- May, 1000 head

SOWFFT = Sow farrowings in the fall (June-November), 1000 head

PPORK = PORKPT/CPIT where

PORKPT is price of barrows and gilts in seven market, \$/cwt.

CPIT is consumer price index, 1967=1.0

CORNP = CORNPT/CPIT where

CORNPT is farm price of corn, \$/bushel

SOYMP = SOYMPT/CPIT where

SOYMPT is farm price of soymeal, \$/cwt.

PPLS = Average Pigs per Litter, December(t-1)-May, Number

PPLF = Average Pigs per Litter, June-November, Number

PCS = Pig crop inventory, December(t-1)-May, 1000 head

PCF = Pig crop inventory, June-November, 1000 head

TPC = Total pig crop inventory, 1000 head

DLPC = Death loss as percent of total pig crop

PCSS = Pig crop surviving in the spring, 1000 head

PCSF = Pig crop surviving in the fall, 1000 head

GSS = Gilts surviving in the spring, 1000 head

GSF = Giltss surviving in the fall, 1000 head

PGRS = GRTS/GSF(-1), Percent of gilts retained in spring

PGRF = GRTF/GSS, Percent of gilts retained in the fall

GRTS = Number of gilts retained in the spring, 1000 head

GRTF = Number of gilts retained in the fall, 1000 head

SLBGS = Commercial slaughter of barrows and gilts, December(t-1)- May, 1000 head

SLBGF = Commercial slaughter of barrow and gilts, June-November, 1000 head

SSS = Commercial slaughter of sows, December(t-1)-May, 1000 head

SSF = Commercial slaughter of sows, June-November, 1000 head

ADWHG = Average dressed weight of hogs, pounds

TSLHG = Total commercial slaughter of hogs, 1000 head

PORKQT = Commercial hog production, million pounds

The biological trend are approximated by a cubic spline. The specific form of the spline will be presented in section 6.4. Total production of hogs is determined by the number of hogs marketed and their average dressed weight. The number of hogs marketed is a function of the number of sows that farrowed in preceding time periods. Thus, the first step in the analysis is the estimation of spring and fall farrowings.

The nature of hog production indicates that a single equation least squares model is adequate in estimating the number of sows farrowing. The number of sows farrowing cannot be altered immediately in response to changes in economic variables during the farrowing period. This is due to the biological lags involved in hog production. For instance, the gestation period for hogs is usually four months. Most decisions regarding how many sows to farrow are made at or before breeding time. Hence, the number of sows farrowing is expressed as a function of predetermined variables.

The number of pigs per litter is largely a function of the genetic quality of the breeding herd, management ability of the producer, and weather conditions. As mentioned earlier, pigs per litter has been trending upward in recent years due to the improved management and genetics in hog production. The litter size equation for spring and fall are both specified to be primarily explained by the trend in these factors. A flexible time trend in the form of a cubic spline is used to explain pigs per litter. The flexible trend specification will allow for the gradual but varying rates of change in pigs per litter as observed in the actual time series data.

The size of the pig crop during spring and fall are approximated by multiplying sows farrowing and pigs per litter for the corresponding periods. The inventory of pigs on farms are not all slaughtered due to death loss and additions to the breeding herd. The size of the pig crops in spring and fall are adjusted to reflect death losses. From the pig crop, the surviving barrows and gilts become part of the market hog inventory and are put on feed. When the pigs on feed have matured to market weight, they are either slaughtered or retained for the breeding herd. In this stage, barrows are taken to slaughter and the farmer decides how may gilts will be retained as additions to the breeding herd and how many will be slaughtered.

The percent of gilts retained for breeding in the present analysis was hypothesized to be primarily explained by the current age and composition of the breeding herd, farmer's price expectations and feed costs. Slaughter of barrows and gilts and sows slaughter together determine total hog slaughter which then determine pounds of pork produced.

6.4 Empirical Results

The equations of the model are estimated using ordinary least squares. The empirical results are presented in Equations 6.1 through 6.16. The models as a whole appear to fit very well, as evidenced by the R^2 and t-values for the estimated parameters. All estimated parameters in the models are consistent with a priori expectations of the signs.

Consistent with economic theory, the hog price variable has a positive sign while the corn price variable has a negative sign in the sows farrowing and slaughter equations (Equation 6.1, 6.2, 6.15, and 6.16). The introduction of the flexible trend in the sows farrowing equations yields a significant improvement in fit compared to the base model presented in Chapter 3.

The flexible trend variable accounted for more than 87 percent of the variation in pigs per litter in spring

Equation 6.1

SMPL 1958 - 1985
28 Observations
LS // Dependent Variable is SOWFST
Convergence achieved after 3 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	5416.2021	1490.0305	3.6349606	0.002
T	-515.52490	174.99350	-2.9459660	0.009
T2	30.240379	15.677316	1.9289257	0.071
T3	-0.5986261	0.4360020	-1.3729893	0.188
Z15	0.1828031	0.7346021	0.2488464	0.806
SOWFFT(-1)	0.7634110	0.1601369	4.7672408	0.000
CORNP(-2)	-1104.3180	300.64851	-3.6731199	0.002
SOYMP(-1)	-84.776563	57.896063	-1.4642889	0.161
SOYMP(-2)	-208.92350	58.871987	-3.5487760	0.002
PPORK(-1)	99.118685	20.526705	4.8287674	0.000
AR(1)	-0.4857395	0.2206683	-2.2012199	0.042

R-squared	0.901036	Mean of dependent var	6494.036
Adjusted R-squared	0.842822	S.D. of dependent var	664.9369
S.E. of regression	263.6187	Sum of squared resid	1181412.
Durbin-Watson stat	1.970809	F-statistic	15.47799
Log likelihood	-188.8305		

Equation 6.2

SMPL 1958 - 1985
28 Observations
LS // Dependent Variable is SOWFFT
Convergence achieved after 3 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	1309.0959	1733.3674	0.7552328	0.460
T	420.77451	158.70334	2.6513275	0.017
T2	-35.603914	13.333751	-2.6702099	0.016
T3	1.0546881	0.3574014	2.9509907	0.009
Z15	-2.0661308	0.5794753	-3.5655197	0.002
SOWFST	0.5616611	0.1392323	4.0339846	0.001
CORNP(-2)	-776.13745	348.72977	-2.2256128	0.040
SOYMP(-1)	-138.48914	51.229973	-2.7032835	0.015
SOYMP(-2)	-183.75351	55.176091	-3.3303105	0.004
PPORK(-1)	62.538381	19.897746	3.1429882	0.006
AR(1)	-0.3943437	0.2535278	-1.5554258	0.138

R-squared	0.878966	Mean of dependent var	5986.357
Adjusted R-squared	0.807769	S.D. of dependent var	491.4092
S.E. of regression	215.4540	Sum of squared resid	789147.0
Durbin-Watson stat	2.019435	F-statistic	12.34563
Log likelihood	-183.1813		

Equation 6.3

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is PPLF

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	7.0234839	0.0452846	155.09640	0.000
T	0.0126048	0.0024705	5.1021827	0.000

R-squared	0.473036	Mean of dependent var	7.225161
Adjusted R-squared	0.454865	S.D. of dependent var	0.166631
S.E. of regression	0.123029	Sum of squared resid	0.438947
Durbin-Watson stat	0.532835	F-statistic	26.03227
Log likelihood	22.00204		

Equation 6.4

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is PPLF

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	6.9076191	0.0331066	208.64761	0.000
T	0.0322143	0.0036412	8.8470567	0.000
DVT70	-0.0385173	0.0076327	-5.0463730	0.000
DV70ON	2.4895287	0.5489455	4.5351113	0.000
DV80ON	-6.7737660	1.3017733	-5.2034914	0.000
DVT80	0.0857316	0.0160355	5.3463596	0.000

R-squared	0.888579	Mean of dependent var	7.225161
Adjusted R-squared	0.866295	S.D. of dependent var	0.166631
S.E. of regression	0.060930	Sum of squared resid	0.092811
Durbin-Watson stat	1.806700	F-statistic	39.87496
Log likelihood	46.08622		

Equation 6.5

SMPL 1956 - 1985

30 Observations

LS // Dependent Variable is PPLF

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	7.0960815	0.1078366	65.804038	0.000
T	-0.0464431	0.0421841	-1.1009627	0.282
T2	0.0105615	0.0046366	2.2778796	0.032
T3	-0.0004398	0.0001508	-2.9173567	0.008
Z13	0.0008904	0.0002330	3.8213959	0.001
Z24	-0.0007139	0.0005304	-1.3459768	0.191

R-squared	0.874540	Mean of dependent var	7.239000
Adjusted R-squared	0.848403	S.D. of dependent var	0.150272
S.E. of regression	0.058509	Sum of squared resid	0.082160
Durbin-Watson stat	1.937080	F-statistic	33.45925
Log likelihood	45.93613		

Equation 6.6
SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPLS

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	7.0219355	0.0505890	138.80363	0.000
T	0.0118347	0.0027599	4.2881498	0.000

R-squared	0.388034	Mean of dependent var	7.211290
Adjusted R-squared	0.366931	S.D. of dependent var	0.172738
S.E. of regression	0.137440	Sum of squared resid	0.547801
Durbin-Watson stat	0.739113	F-statistic	18.38823
Log likelihood	18.56829		

Equation 6.7
SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPLS

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	6.9469935	0.0402212	172.71957	0.000
T	0.0237668	0.0037158	6.3961236	0.000
DVT73	-0.0416239	0.0158972	-2.6183137	0.015
DV73ON	2.8178406	1.1987373	2.3506740	0.027
DVT80	0.0867143	0.0249234	3.4792260	0.002
DV80ON	-6.7338070	1.9959505	-3.3737345	0.002

R-squared	0.813170	Mean of dependent var	7.211290
Adjusted R-squared	0.775805	S.D. of dependent var	0.172738
S.E. of regression	0.081790	Sum of squared resid	0.167240
Durbin-Watson stat	1.894334	F-statistic	21.76237
Log likelihood	36.95874		

Equation 6.8
SMPL 1955 - 1985
31 Observations
LS // Dependent Variable is PPLS

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	6.8987619	0.0385647	178.88789	0.000
T	0.0318214	0.0042416	7.5023043	0.000
DVT70	-0.0566699	0.0088910	-6.3738305	0.000
DV70ON	3.8388074	0.6394469	6.0033250	0.000
DV80ON	-7.2715905	1.5163890	-4.7953332	0.000
DVT80	0.0937056	0.0186792	5.0165772	0.000

R-squared	0.859313	Mean of dependent var	7.211290
Adjusted R-squared	0.831176	S.D. of dependent var	0.172738
S.E. of regression	0.070975	Sum of squared resid	0.125935
Durbin-Watson stat	2.612293	F-statistic	30.53995
Log likelihood	41.35549		

Equation 6.9

SMPL 1955 - 1985

31 Observations

LS // Dependent Variable is PPLS

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	7.0079007	0.0985044	71.143052	0.000
T	-0.0404801	0.0430062	-0.9412614	0.356
T2	0.0113627	0.0050633	2.2441234	0.034
T3	-0.0004913	0.0001714	-2.8667083	0.008
Z13	0.0010138	0.0002829	3.5831909	0.001
Z24	-0.0009484	0.0007414	-1.2791826	0.213

R-squared	0.804568	Mean of dependent var	7.211290
Adjusted R-squared	0.765505	S.D. of dependent var	0.172738
S.E. of regression	0.083648	Sum of squared resid	0.174923
Durbin-Watson stat	2.069869	F-statistic	20.58691
Log likelihood	36.26255		

Equation 6.10

SMPL 1957 - 1985
29 Observations
LS // Dependent Variable is ADWHG

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	128.62934	1.7649206	72.881093	0.000
PPORK(-1)	0.1126049	0.0778994	1.4455160	0.163
CORNP(-1)	-1.5502158	1.0920193	-1.4195864	0.170
T	1.6008690	0.0556383	28.772804	0.000
DVT73	-0.3378975	0.1910220	-1.7688933	0.091
DV730N	28.999420	14.589476	1.9876944	0.060
DVT80	-0.8522642	0.2811884	-3.0309366	0.006
DV800N	67.432237	22.417950	3.0079573	0.007

R-squared	0.996823	Mean of dependent var	156.6552
Adjusted R-squared	0.995764	S.D. of dependent var	13.78217
S.E. of regression	0.897050	Sum of squared resid	16.89866
Durbin-Watson stat	1.761899	F-statistic	941.1964
Log likelihood	-33.31833		

Equation 6.11

SMPL 1970 - 1985
16 Observations
LS // Dependent Variable is ADWHG

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	150.39994	2.5892887	58.085428	0.000
T70	4.1192353	1.0431574	3.9488148	0.003
T702	-0.1969937	0.2166073	-0.9094506	0.387
T703	0.0009973	0.0128503	0.0776099	0.940
Z8	0.0102339	0.0239322	0.4276203	0.679
PPORK(-1)	0.1337640	0.0958067	1.3961855	0.196
CORNP(-2)	-3.4579813	0.9244944	-3.7404028	0.005

R-squared	0.990602	Mean of dependent var	167.5000
Adjusted R-squared	0.984337	S.D. of dependent var	6.449806
S.E. of regression	0.807198	Sum of squared resid	5.864115
Durbin-Watson stat	2.160105	F-statistic	158.1149
Log likelihood	-14.67312		

Equation 6.12

SMPL 1960 - 1985
26 Observations
LS // Dependent Variable is ADWHG
Convergence achieved after 4 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	101.60734	7.8974245	12.865884	0.000
T	3.4631116	1.4374864	2.4091439	0.028
T2	-0.2601173	0.1233734	-2.1083736	0.050
T3	0.0080649	0.0032124	2.5105353	0.022
Z15	-0.0156955	0.0043043	-3.6464872	0.002
GMHGD(-1)	-0.1376434	0.0774465	-1.7772698	0.093
SOYMP(-2)	0.5872213	0.1985564	2.9574530	0.009
DINC	0.0102449	0.0024259	4.2231015	0.001
AR(1)	-0.3020236	0.2544096	-1.1871550	0.251

R-squared	0.996143	Mean of dependent var	159.1154
Adjusted R-squared	0.994327	S.D. of dependent var	12.31041
S.E. of regression	0.927174	Sum of squared resid	14.61409
Durbin-Watson stat	2.135893	F-statistic	548.7741
Log likelihood	-29.40297		

Equation 6.13

SMPL 1973 - 1985

13 Observations

LS // Dependent Variable is SSF

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	-22031.957	5626.0412	-3.9160674	0.017
T70	10748.769	2822.7744	3.8078740	0.019
T702	-1409.7691	380.30032	-3.7069890	0.021
T703	59.474051	16.489934	3.6066883	0.023
Z8	-58.975384	17.694373	-3.3330023	0.029
PPORK(-2)	-88.680391	27.411892	-3.2351066	0.032
CORNP(-2)	-964.55504	362.80595	-2.6585976	0.056
SOYMP(-2)	-89.224062	49.149999	-1.8153421	0.144
SSS	0.5893629	0.1166796	5.0511221	0.007

R-squared	0.971868	Mean of dependent var	2408.538
Adjusted R-squared	0.915604	S.D. of dependent var	422.9887
S.E. of regression	122.8824	Sum of squared resid	60400.37
Durbin-Watson stat	3.374354	F-statistic	17.27334
Log likelihood	-73.33091		

Equation 6.14

SMPL 1973 - 1985

13 Observations

LS // Dependent Variable is SSS

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	21977.766	4931.2669	4.4568194	0.011
T70	-11087.585	2604.0322	-4.2578526	0.013
T702	1515.9787	353.80313	4.2848086	0.013
T703	-65.804454	15.325561	-4.2937713	0.013
Z8	68.174854	16.078114	4.2402270	0.013
PPORK(-1)	100.68629	29.457063	3.4180694	0.027
CORNP(-2)	512.31090	268.27696	1.9096343	0.129
SOYMP(-2)	141.86970	32.012800	4.4316556	0.011
SSF(-1)	0.5340359	0.0818668	6.5232297	0.003

R-squared	0.963234	Mean of dependent var	2071.769
Adjusted R-squared	0.889702	S.D. of dependent var	263.5185
S.E. of regression	87.51760	Sum of squared resid	30637.32
Durbin-Watson stat	2.286397	F-statistic	13.09950
Log likelihood	-68.91886		

Equation 6.15

SMPL 1971 - 1985
15 Observations
LS // Dependent Variable is PGRF

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	0.0794555	0.0581327	1.3667958	0.221
T70	0.0744047	0.0434572	1.7121398	0.138
T702	-0.0075548	0.0067232	-1.1236911	0.304
T703	0.0002091	0.0003294	0.6347211	0.549
Z8	4.572D-05	0.0004915	0.0930176	0.929
PPORK(-1)	-0.0034863	0.0014208	-2.4538038	0.050
CORNP(-2)	-0.0281096	0.0230088	-1.2216891	0.268
SOYMP(-1)	-0.0072603	0.0046961	-1.5460223	0.173
INTT	-0.0019877	0.0021522	-0.9235684	0.391

R-squared	0.701174	Mean of dependent var	0.099594
Adjusted R-squared	0.302739	S.D. of dependent var	0.017558
S.E. of regression	0.014661	Sum of squared resid	0.001290
Durbin-Watson stat	2.801468	F-statistic	1.759821
Log likelihood	48.92663		

Equation 6.16

SMPL 1971 - 1985
15 Observations
LS // Dependent Variable is PGRS
Convergence achieved after 8 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	0.1291083	0.0209283	6.1690829	0.000
T70	-0.0007194	0.0127670	-0.0563492	0.957
T702	-0.0006101	0.0022740	-0.2682966	0.796
T703	4.807D-05	0.0001230	0.3907717	0.708
Z8	-9.871D-05	0.0002097	-0.4706753	0.652
GMHGD	0.0047078	0.0010766	4.3728468	0.003
INTT	-0.0031623	0.0010919	-2.8960609	0.023
AR(1)	-0.5516455	0.2211522	-2.4944153	0.041

R-squared	0.920664	Mean of dependent var	0.113887
Adjusted R-squared	0.841329	S.D. of dependent var	0.021980
S.E. of regression	0.008755	Sum of squared resid	0.000537
Durbin-Watson stat	1.974034	F-statistic	11.60466
Log likelihood	55.50346		

Figure 6.5

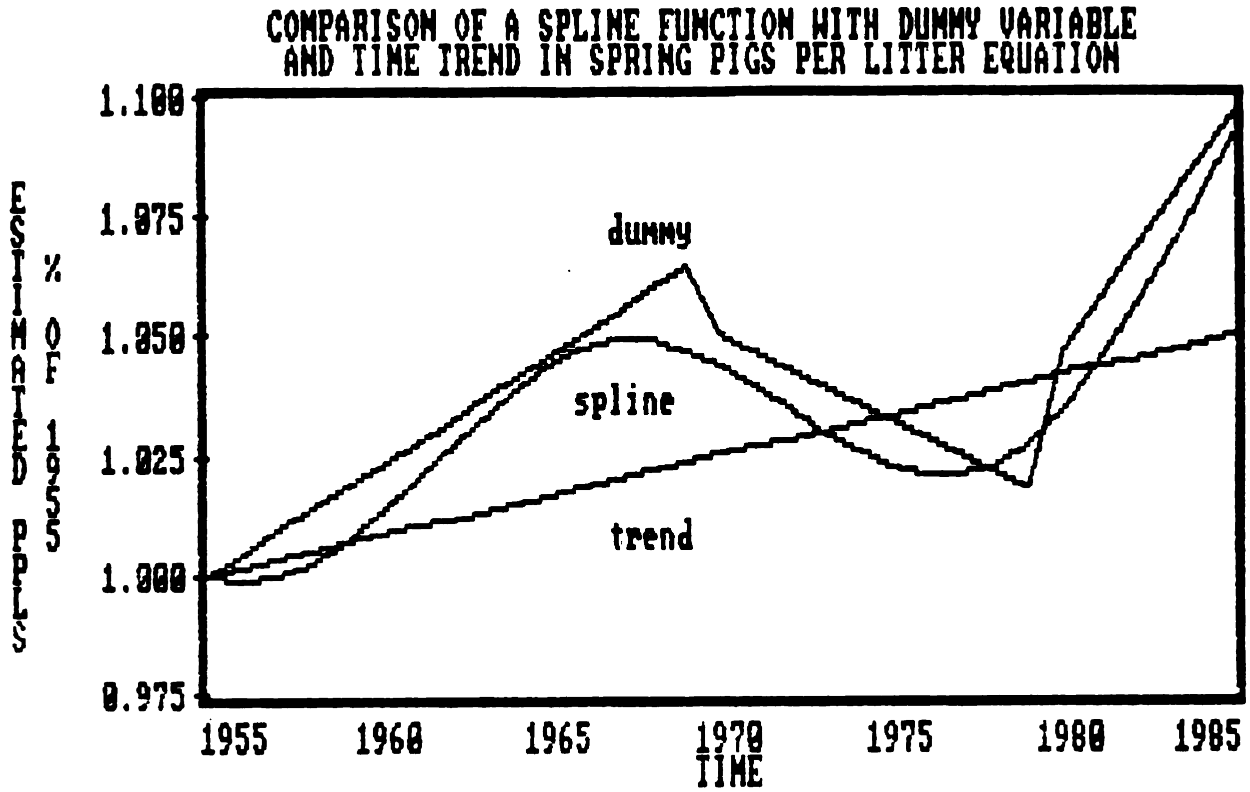


Figure 6.6

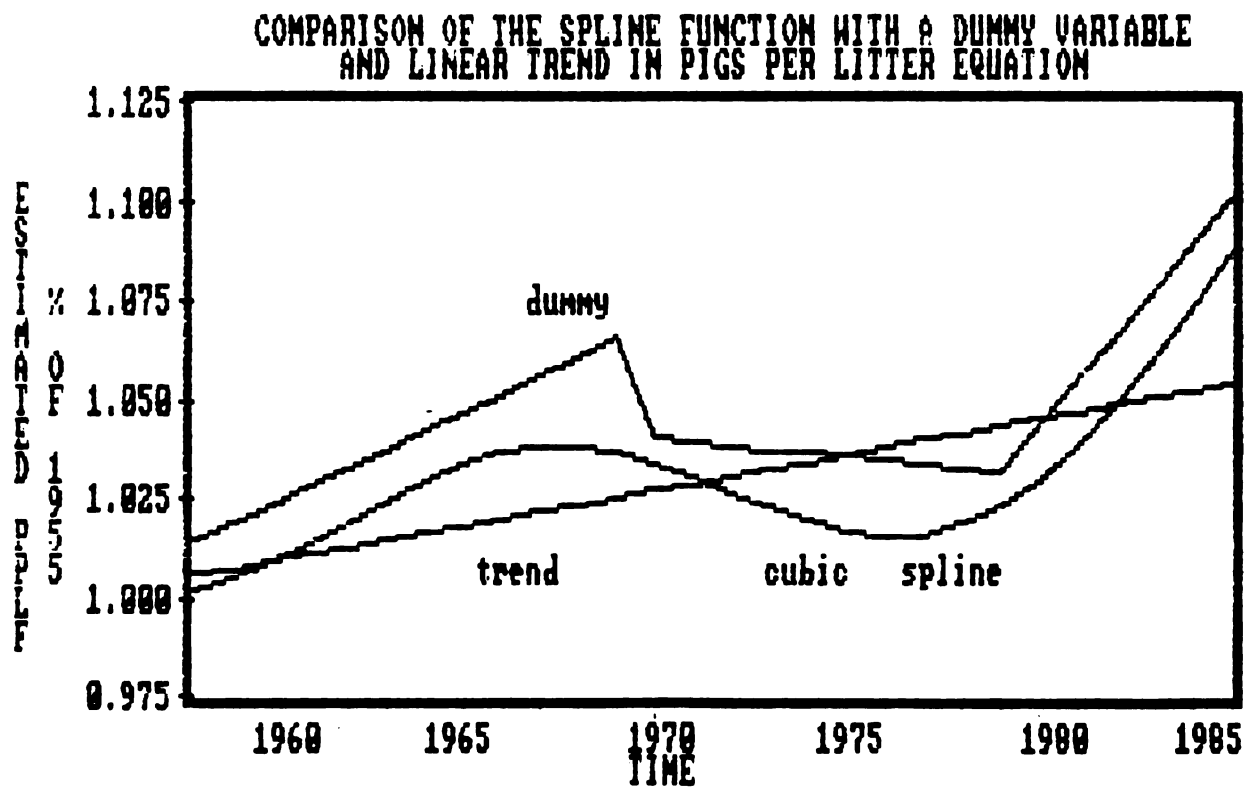


Figure 6.7

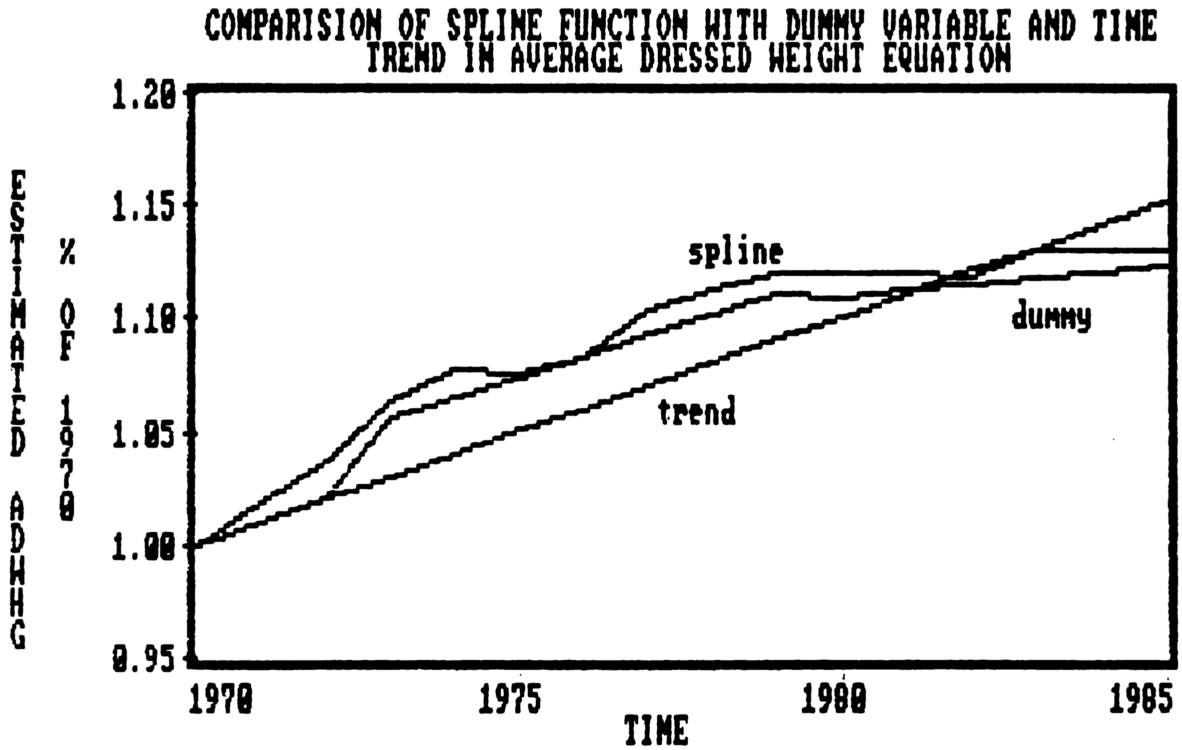

COMPARISION OF SPLINE FUNCTION WITH DUMMY VARIABLE AND TIME
TREND IN AVERAGE DRESSED WEIGHT EQUATION
ESTIMATED ADWHG
% OF 1970
1.20
1.15
1.10
1.05
1.00
0.95
spline
dummy
trend
1970
1975
1980
1985
TIME

Figure 6.8

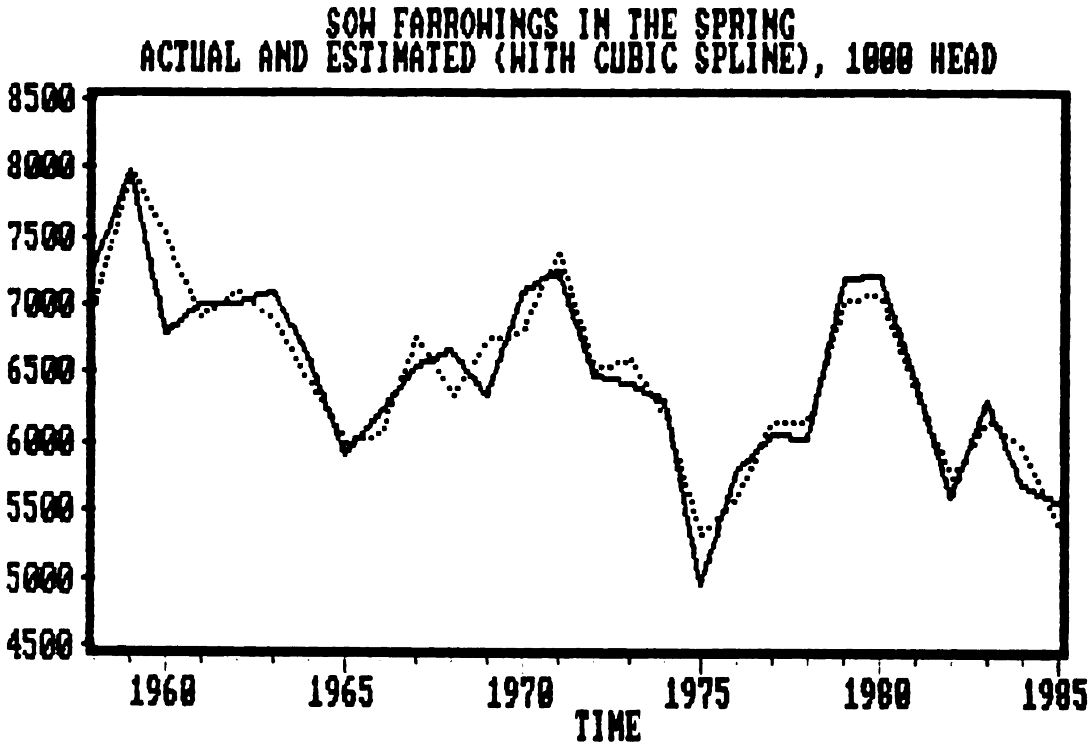


Figure 6.9

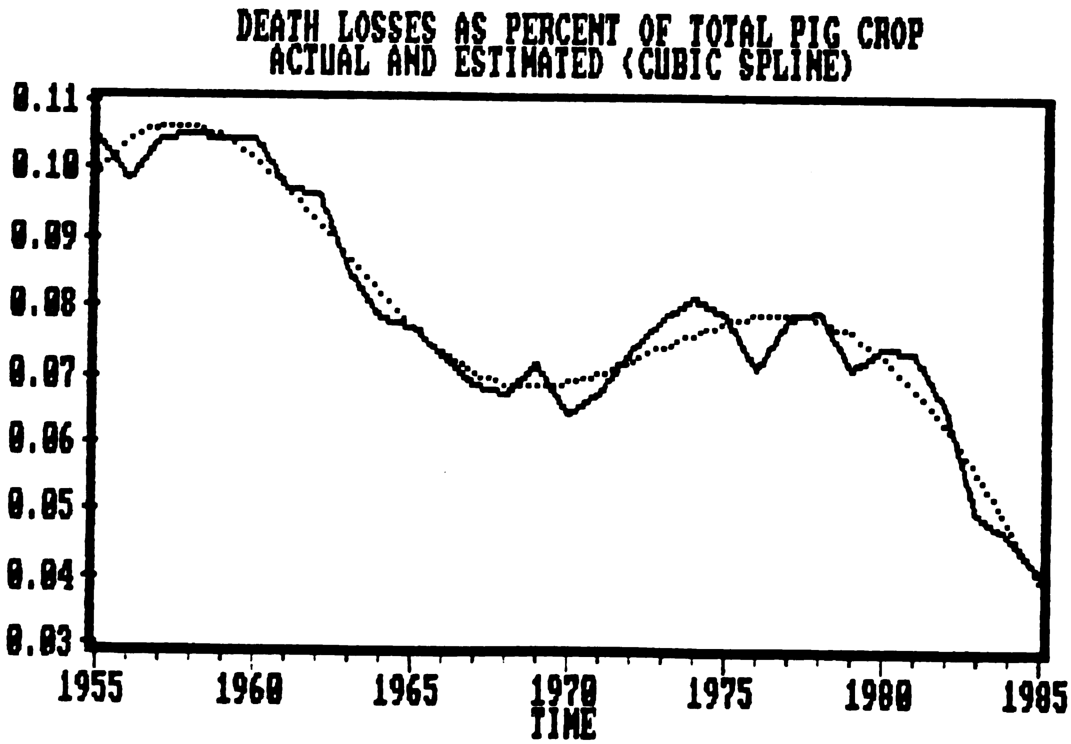


Figure 6.10

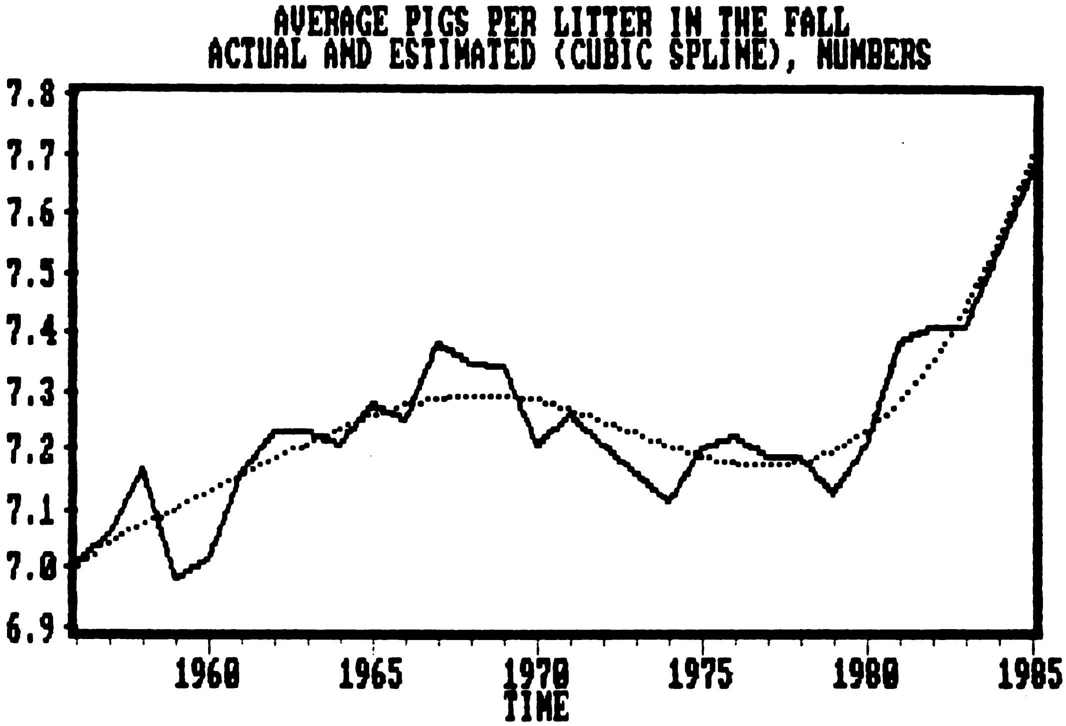
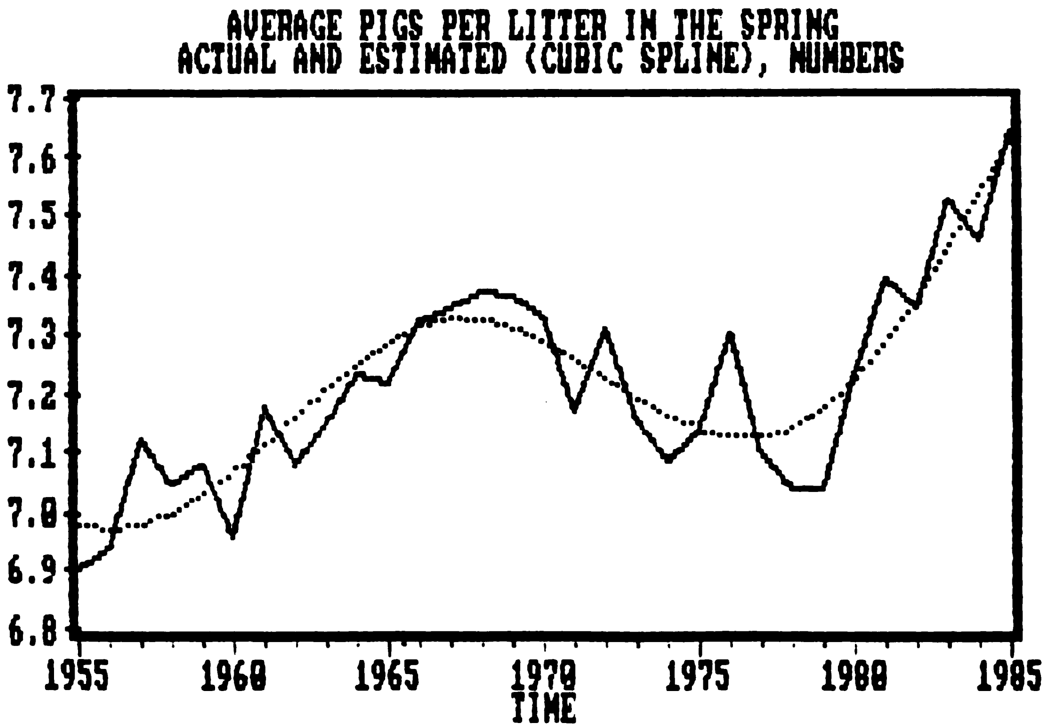


Figure 6.11



(Equation 6.5). The Durbin-watson statistic indicates absence of serial correlation in PPLF and PPLS equations. A conventional time trend for litter size for both spring and fall are also estimated (Equation 6.3 and 6.6). The traditional linear trend specification of the pigs per litter in the fall equation is observed to be inadequate as seen by overpredictions during 1972-1980 and underpredictions during 1973-1985. The plot of the OLS residuals indicate misspecification when a linear trend was specified for both PPLS and PPLF variables.

To account for the shifts in the trend in pigs per litter during the 1970s, shifter variables were introduced (Equation 6.4 and 6.7). DVT70 and DVT80 which allows abrupt shifts the rate of increase in litter size in 1970 and 1980 were included. Also, intercept shifters corresponding to the these years were introduced. Based on F-test, the shifter variables are significant at the .05 level. The introduction of the shifter variables yields a significant improvement in fit compared to the litter size equation with just the linear trend.

A flexible trend in pigs per litter were also estimated (Equation 6.5 and 6.9). The hypothesis is that changes in pigs per litter will vary from year to year. This variation in the trend in average litter size may be explained by potential variations in the quality of the breeding herd over time. Hence, a specification which allows a shift upward over some periods and downward over others may be better. A cubic spline is used to approximate the flexible trend in litter size.

The pigs per litter in fall and spring were estimated using a flexible trend. Z13 and Z24 represents the knot in 1967 and 1978, respectively. The flexible trend specification also led to significant improvement in the fit and a reduction of serial correlation. The Durbin-Watson statistic shows absence of autocorrelation in the residuals from both litter size equations with a flexible trend.

It is interesting to compare the shifts in pigs per litter implied by the three alternative trend models. Table 6. shows the estimated trend level of pigs per litter in spring and fall expressed as a percentage of the 1955 level. That is, the figures in Table represent the estimated number of pigs per litter size as a percentage of 1955 litter size. PPLFT, PPLFD, and PPLFS are the values for the pigs per litter in fall with a linear trend, dummy, and flexible trends, respectively. The plot of these values is shown in Figure 6.5 and 6.6.

The linear time trend corresponds to a steady increase in pigs per litter (fall) at a rate of .18 percent per year. At this rate, pigs per litter in the fall increase only about 5.6 percent over the sample period. The specification with intercept and trend shifters showed a higher rate of increase of pigs per litter in the fall compared to the linear trend. Under this specification, PPLF increased at a rate of about .5 percent per year from 1956 to 1969. An abrupt decline in fall litter size at about .04 per year (coefficient of DVT70) occurred starting in 1970. From 1970, a decline at a rate of .08 percent per year is indicated. Beginning 1980, the trend shifted upward at a rate of 1.05 percent per year.

With a flexible trend, PPLF was allowed to shift at varying rates over the sample period. Compared with the estimates from the linear trend, the estimated values from the flexible trend specification are closer to actual values.

Similar results are shown for pigs per litter in spring equation. That is, the introduction of flexible trend yield significant improvement in the fit to the data compared to the linear trend specification. In this case, the trend and intercept shifters indicate very similar fit with the flexible trend.

Estimation results of percent of gilts retained (additions to the breeding herd) indicate that the latter is largely explained by variations in the gross margin (difference between hog price and feed prices) and cost of money measured by the interest rate (see Equation 13 and 6.14). The gross margin variable has a positive sign, indicating that more gilts are retained for breeding as prices of hogs relative to feed prices increase. Percent of gilts retained, however, declines as cost of money increase.

Estimation results of sows slaughter are presented in Equation 6.15 and 6.16. The negative trend in sow slaughter is captured by the flexible trend variable. Estimated value of sow slaughter in spring and fall in 1985 is shown to be only about 87 and 92 percent of their 1973 level. The coefficients of hog price and feed prices indicate that slaughter of sows increase as output and input prices increase.

Estimation results for average dressed weights of hogs are shown in Equations 6.14 to 6.17. The three trend specifications were estimated. The average dressed weight equation with linear trend indicate an constant increase of 1.57 pounds per year. The plot of the OLS residuals indicate quite large overpredictions starting in 1973 and underpredictions beginning in 1982.

The introduction of a trend and intercept shifter in 1970 and 1980 yield a significant improvement in fit to the data. The Durbin-Watson statistic indicate a reduction of serial correlation. A decline of about .24 pounds per year in dressed weights of hogs is indicated starting in 1973. The coefficient of DVT80 correspond to about .96 pounds decrease per year starting in 1980.

A flexible trend is introduced in the average dressed weight equation to represent the varying rates of change in weight of hogs as a result of improvement in biological technology and management practices. Economic variables such as hog and corn prices are also introduced to consider the effects of prices on market weight of hogs. Estimated dressed weight in 1985 from this equation is about 13 percent over the 1970 level. This represents a very slight increase compared with those estimated from Equation 6. with the intercept and trend shifters.

The coefficient on hog price is positive. This implies that market weight of hogs increases as hog prices rise. On the other hand, an increase in the price of feed (represented by corn price) leads to a decline in market weight. The equation with flexible trend specification is has better statistical properties than the two alternative models.

6.5 Summary and Conclusions

Physical and biological relationships such as birth, replacement, death can be used as conditioning mechanisms for modeling pork production. The latter is determined based on long-term biological and technical ratios and trends. Any deviation from the long run trend is explained by changes in relevant economic variables. Changes in biological relationships are included as restrictions in the pork supply model. The shifts and changes in the biological relationships are approximated by time trend shifters and cubic spline functions.

The model is specified as a recursive model. Hence, single equation ordinary least squares procedure is used. The results indicate good fits as evidenced by R^2 and t-values of the estimated parameters. All estimates have signs consistent with theory.

The introduction of flexible trend yield significant improvement in the fit compared to the linear trend specification. In particular, the pigs per litter equation estimated using cubic spline has very good fit during the historical period. However, projections of pigs per litter based on this equation are beyond reasonable values.

Supply response for livestock is difficult to represent in models designed for forecasting and policy analysis. The difficulty lies in the limited theoretical basis for specifying the lag adjustments in the production stages. The specification of the pork supply model in this study allows an explicit consideration of biological and physical relationships constraining pork production. By considering the information about the physical and biological factors with those of economic variables, the structure of the model attains consistency and provides more accurate estimates.

CHAPTER 7

MODEL VALIDATION AND EVALUATION OF THE EFFECTS OF STRUCTURAL CHANGE ON LIVESTOCK PRODUCTION AND PRICES

In chapter 5, the null hypothesis of constant parameters in the demand for beef, pork and broilers, for the period 1955-1985 was rejected at the 5 percent significance level. On the other hand, the null hypothesis of constant parameters for turkey demand was not rejected based at the .05 significance tests. Although the recursive residual analysis provided information about the timing of the structural break, the significance tests based on the recursive residuals only provided evidence about the general instability of the demand parameters. Information about which parameters are significantly changing over time is not evident from the significance tests based on the recursive residuals. However, the plots of recursive parameter estimates were used to determine the behavior and direction of parameter variation. Given these information, the analysis was extended to test more specific hypothesis of pattern of change in parameters. Systematic and gradual continuous variation in the demand parameters were specified using Legendre polynomials and trend variables.

In this chapter, the estimated time-varying parameter models of meat demand are further evaluated. The chapter is outlined as follows: First, the criteria for selecting the most adequate model among alternative specifications are discussed in section 7.1. Second, the model validation procedure is discussed in section 7.2. Section 7.3 presents the results of the discrimination among models based on the model selection criteria. The selected models of demand and supply are integrated in a simulation exercise to evaluate how the entire model as a system tracks historical data. The results of the model validation are then presented in section 7.4. Also the forecasting ability of the fixed parameter model and the time-varying demand parameter models are compared. Selected models are then used to generate long-run projections to evaluate the potential effects of a continuation of the structural change on U.S. livestock production and prices.

7.1 Criteria for Selecting Among Alternative Models

In the context of the demand models considered in this study, structural change in demand is approximated by changes in the demand parameters. However, theoretical considerations provide little guidance about the exact form and behavior of the change in the structure of the demand parameters for the meat commodities considered. Also, there is little theoretical basis for deciding which of the relevant parameters are changing over time. The question of which form of parameter variation is the most appropriate and realistic and which of the parameters are influenced by the structural change are largely empirical questions. The selection of the most adequate approximation of the structural change among the alternative model specification is an important part of the analysis. To aid in this task is the use of two statistical criteria which considers some desirable model characteristics.[1] The two criteria used in selecting among alternative models are those proposed by Schwarz (1978), namely the Akaike Information Criterion (AIC) and the Posterior Probability Criterion (PPC). Both measures consider goodness of fit and relative parsimony characteristics. The forecasting ability of the models will also be considered in the model validation stage.

The most adequate specification based on the AIC measure is one which maximizes the following:

$$(7.1) \quad AIC_i = L_i - q_i$$

where q_i is the number of parameters estimated in the ith demand model and L_i is the maximum of the log-likelihood function of the ith demand model. On the other hand, the optimal model specification based on the PPC measure is one which has the maximum value of the posterior probability criterion measure defined as follows:

$$(7.2) \quad PPC_i = L_i - (q_i/2)\log T$$

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[1] These statistical measures were used by Frank (1983) in a study of gradual switching regressions and retail demand for meat.

By their definition, the AIC and PPC measures are both determined based on the value of the model's likelihood function, a measure of goodness of fit, and the number of parameters estimated.

7.2 Model Validation

The economic and statistical criteria are employed in evaluating the individual model equation and blocks of equations. But more importantly, both the supply and demand equations need to yield good fits when all equations are combined in one integrated system. The ability of the model to track historical data is a critical test for any model.

7.2.1 Historical Simulation

Model validation involves evaluation of the model's ability to duplicate the characteristics of the system being modeled (Johnson and Rausser, 1977). The purpose for which the model was built determines the appropriate validation criteria. Models may be evaluated based on their forecasting ability or on the consistency of the estimated parameters with those dictated by theory.

In this section, the ability of the model to track the historical data series is evaluated. In the historical simulation, historical values are supplied as initial conditions for the endogenous variables. Historical series are used for the exogenous variables. Prediction errors then result from errors in structural specification and parameter estimates. The test of model validity through historical simulation involves the comparison of the actual data series with the simulated values for each endogenous variable.

The criteria used in the evaluation of the entire model as a system are defined in this section. The absolute and relative accuracy evaluation procedures are the two major approaches used in model validation. Absolute accuracy of simulated values is evaluated using statistical measures describing the differences between the simulated and the actual values. Relative accuracy evaluation, on the other hand, involves the comparison of simulation associated with an alternative forecasting approach. Theil's inequality coefficients,[2] in particular, compare forecasts with those generated from a naive no-change model. These coefficients are employed in the validation stage. They are defined as follows:

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[2] The inequality coefficients are introduced in H. Theil, Economic Forecasts and Policy (Amsterdam: North Holland, 1961), pp. 30-37. They are also discussed in H. Theil, Applied Economic Forecasting, (Amsterdam: North Holland, 1966), pp. 26-35.

$$(7.3)\quad U(1) = (\ (\ p(t) - a(t)\ )^2 \ /\ (\ a(t)^2 \ + p(t)^2\ )\ ^{1/2}$$

$$(7.4)\quad U(2) = (\ (\ p(t) - a(t)\ )^2 \ /\ a(t)\ )\ ^{1/2}$$

where p(t) and a(t) are the predicted and actual values, respectively. U(1) lies between 0 and 1. A value of zero suggests perfect prediction. If U(1) equals one, the estimated model is no more accurate in forecasting than a naive no-change model. U(2), on the other hand, is bounded by zero and infinity. If U(2) is greater than one, the estimated model is inferior to that of a naive no-change model. A value of one for U(2) implies that the model is the same as that of a naive model. U(2) with a value less than one suggests a superior model compared to a naive no-change extrapolation.

The numerator of the inequality coefficients can be decomposed to identify the sources of prediction errors. The three components are defined as follows:

$$(7.5)\quad U(m) = (\ P - A\ )^2 \ /\ (\ 1/n\ (\ p(t) - a(t)\ )^2\ )$$

$$(7.6)\quad U(s) = (\ S(p) - S(a)\ )^2 \ /\ (1/n\ (p(t) - a(t)\ )^2\ )$$

$$(7.7)\quad U(c) = 2\ (1-r)\ S(p)S(a)\ /\ (1/n\ (p(t) - a(t)\ )^2\ )$$

where $U(m) + U(s) + U(c) = 1.0$; P and A are the means of the predicted and actual values, respectively; S(p) and S(a) are the standard deviations of the predicted and actual values, respectively; r is the correlation coefficient between the predicted and actual values.

U(m) represents the proportion of the simulation error due to bias. It measures the extent to which the average values of the simulated and actual series deviate from each other. A value of U(m) close to zero indicates good performance of the model. U(s) reflects the proportion of the prediction error due to the difference in the degree of the variability between the simulated and actual values. Preferred values of U(s) are those close to zero. A large value of U(s) indicate that the actual series has large variance, while the simulated values shows small variation or vice versa.

U(c) represents the proportion of the prediction error due to unsystematic or random factors. It represents the remaining error after deviations from average and average variances have been considered. A value of U(c) close to one indicates good ability of the model to track historical series of the endogenous variables.

Among the simplest statistical measures describing absolute accuracy of forecasts is the squared mean error (SME), defined as $E(a-p)^2$. For example, (7.8) $SME = 1/n * \Sigma (a(t) - p(t))^2$

where the a(i) and p(i) are the ith actual and predicted values, respectively. Since the deviations are squared, larger errors reflect a significant decline in model performance. The square root of the SME, called the root squared error of forecasts represents the mean size of the deviations of the simulated variable from its actual time path. Measured in the same units as the actual values, the magnitude of this error is compared with the average size of the variable being considered.

Other measures of simulation performance are the root mean square percent error, mean simulation error, and mean percent error. The root mean square (rms) percent error is defined as follows

(7.9) $\text{rms error} = (1/T \ \Sigma (p - a / a)^2)^{1/2})$

The mean simulation error is defined as

(7.10) $\text{mean error} = \frac{1}{T} \ \Sigma (p - a)$

The mean percent error is defined as

(7.11) $\text{mean percent error} = \frac{1}{T} \ \Sigma (p - a / a) * 100$

Since mean errors may be small or close to zero as large positive and negative errors cancel out each other, the rms simulation error is a better measure of the simulation performance. Another important criterion to evaluate the model's performance is how well the model simulates turning points in the historical series.

In addition to the absolute and relative accuracy performance critiria discussed above, the model validation will be extended to include the investigation of the model's sensitivity to such factors as the initial period in which the simulation is started, and changes in the time paths of some exogenous variables. The historical simulation will be conducted for the period 1965-1985 and 1975-1985. Whether the model responds to stimuli in a way that is consistent with economic theory and empirical observation is another criterion of model performance.[3]

7.3 Discrimination Among Alternative Demand Models

Values of the Akaike criterion (AIC) and the Posterior Probability criterion (PPC) are presented in Table 7.1. Based on both criteria, any of the models which allows parameters to vary over time is superior to a constant parameter model. This result provides empirical support to the hypothesis of parameter variation in the inverse demand for beef, pork, and broilers.

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[3] These measures are discussed in H.T. Shapiro, "Is Verification Possible? The Evaluation of Large Econometric Models," American Journal of Agricultural Economics, Vol. 55, May, 1973; Also see R. Fair, "An Evaluation of a Short-Run Forecasting Model," International Economic Review, June, 1964.

Table 7.1 Akaike Information Criterion (AIC) and Posterior Probability Criterion (PPC) of Alternative Inverse Demand Models for Meat

MODEL SPECIFICATION	PERIOD	LOG LIKELIHOOD	AIC	PPC
A. MODELS WITHOUT TREND VARIABLE				
FBP = F(C, BFPC, PKPC, POULPC, DINC, DV70ON)*	1955-19	-57	-64	-69
FBP = F(C, BFPC, PKPC, POULPC, DINC)	1970-19	-32	-37	-39
PPORK = F(C, BFPC, PKPC, POULPC, DINC, DV70ON)*	1955-19	-60	-68	-73
PPORK = F(C, BFPC, PKPC, POULPC, DINC)	1970-19	-28	-33	-35
CHP = F(C, BFPC, PKPC, POULPC, DINC, DV70ON)*	1955-19	-36	-43	-48
CHP = F(C, BFPC, PKPC, POULPC, DINC)	1970-19	-20	-25	-27
TKP = F(C, BFPC, PKPC, POULPC, DINC, DV70ON)*	1955-19	-56	-63	-68
TKP = F(C, BFPC, PKPC, POULPC, DINC)	1970-19	-29	-35	-37
B. MODELS WITH TREND VARIABLE				
FBP = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)	1955-1985			
FBP = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)	1970-1985			
PPORK = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)	1955-19	-53	-60	-65
PPORK = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)	1970-19	-21	-28	-30
PPORK = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)*	1956-19	-46	-54	-59
PPORK = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)*	1970-19	-17	-25	-28
CHP = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)	1955-19	-53	-60	-65
CHP = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)*	1956-19	-35	-43	-49
CHP = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)	1970-19	-18	-25	-28
CHP = F(C, BFPC, PKPC, POULPC, DINC, T5576, T77ON)*	1970-19	-18	-26	-29

* Equation is adjusted for serial correlation with Cochrane-Orcutt Procedure.

Table 7.1 (continued)

MODEL SPECIFICATION	PERIOD	LOG LIKELIHOOD	AIC	PPC
TKP = F(C, BFPC, PKPC, POULPC, DINC, T5576, T770N)	1955-19	-57	-64	-69
TKP = F(C, BFPC, PKPC, POULPC, DINC, T5576, T770N)	1970-19	-25	-32	-34
TKP = F(C, BFPC, PKPC, POULPC, DINC, DV700N)*	1970-19	-22	-30	-33
C. FARLEY AND HINICH MODELS				
FBP = F(C, BFPC, LBFPC, POULPC, DINC)	1955-19	-71	-76	-79
FBP = F(C, BFPC, LBFPC, POULPC, DINC)*	1956-19	-56	-62	-66
FBP = F(C, BFPC, LBFPC, PKPC, CHPC, DINC)	1955-19	-72	-78	-82
FBP = F(C, BFPC, LBFPC, PKPC, CHPC, DINC)*	1956-19	-55	-62	-67
FBP = F(C, BFPC, LBFPC, CHPC, LCHPC, PKPC, DINC)	1956-19	-48	-55	-60
FBP = F(C, BFPC, LBFPC, CHPC, LCHPC, PKPC, DINC)*	1956-19	-46	-54	-60
FBP = F(C, BFPC, LBFPC, CHPC, CHPC79, DV79, PKPC, DINC)	1955-19	-46	-54	-60
FBP = F(C, BFPC, LBFPC, POULPC, POUL79, DV79, PKPC, DINC)	1955-19	-48	-56	-62
FBP = F(C, BFPC, DBFC73, CHPC, DCHC76, PKPC, DINC, DV76)	1955-19	-53	-61	-66
PPORK = F(C, BFPC, PKPC, LPKPC, CHPC, DINC)	1955-19	-66	-73	-77
PPORK = F(C, BFPC, PKPC, LPKPC, CHPC, DINC, LDINC)	1955-19	-54	-61	-66
PPORK = F(C, BFPC, PKPC, LPKPC, POULPC, DINC)	1955-19	-66	-72	-76
CHP = F(C, BFPC, PKPC, CHPC, LCHPC, DINC)	1955-19	-51	-57	-61

LBFPC = t/n * BFPC where t = 1,2,..., n
LCHPC = t/n * CHPC
LPKPC = t/n * PKPC
LDINC = t/n * DINC
CHPC79 = CHPC - CHPC IN 1979
DBFC73 = BFPC - BFPC IN 1973
DCHC76 = CHPC - CHPC IN 1976

Table 7.1 (Continued)

MODEL SPECIFICATION	PERIOD	LOG-LIKELIHOOD	AIC	PPC
CHP = F(C, BFPC, LBFPC, PKPC, CHPC, LCHPC, DINC)	1956-198	-42	-49	-54
CHP = F(C, BFPC, PKPC, CHPC, LCHPC, DINC, LDINC)	1956-198	-40	-47	-52
TKP = F(C, BFPC, LBFPC, PKPC, TKPC, CHPC, DINC)	1955-198	-58	-65	-70
TKP = F(C, BFPC, LBFPC, PKPC, TKPC, CHPC, DINC, LDINC)	1955-198	-58	-66	-71
TKP = F(C, BFPC, PKPC, CHPC, TKPC, LTKPC, DINC)	1955-198	-59	-66	-71
TKP = F(C, BFPC, PKPC, CHPC, LCHPC, TKPC, DINC)	1955-198	-59	-66	-71
D. CONTINOUS TIME-VARYING PARAMETER MODELS WITH LEGENDRE POLYNOMIALS				
FBP = F(C, BFPC, P1QB, P2QB, PKPC, POULPC, DINC)	1955-198	-53	-60	-65
FBP = F(C, BFPC, P1QB, P2QB, P3QB, PKPC, POULPC, DINC)	1955-198	-43	-51	-56
FBP = F(C, BFPC, P1QB, P2QB, P3QB, PKPC, POULPC, DINC, P1Y)	1955-198	-39	-48	-55
FBP = F(C, BFPC, P1QB, P2QB, PKPC, P1PK, POULPC, P1POUL, DINC)	1955-198	-46	-55	-62
FBP = F(C, BFPC, P1QB, P2QB, PKPC, P1PK, POULPC, P1POUL, P2POUL, DINC, DV77ON)	1955-198	-32	-43	-51
FBP = F(C, BFPC, P1QB, P2QB, PKPC, P1PK, P1PK, POULPC, P1POUL, P2POUL, DINC)	1955-198	-41	-51	-58

P1QB = LPT1 * BFPC where LPT1 is first degree Legendre polynomial
P2QB = LPT2 * BFPC where LPT2 is second degree Legendre Polynomial
P3QB = LPT3 * BFPC where LPT3 is third degree Legendre Polynomial
P1Y = LPT1 * DINC
P1PK = LPT1 * PKPC
P1POUL = LPT1 * POULPC
P2POUL = LPT2 * POULPC
DV77ON = 0 for t < 1977 and 1 for 1977-1985

Table 7.1 (Continued)

MMODEL SPECIFICATION	PERIOD	LOG-LIKELIHOOD	AIC	PPC
FBP = F(C, BFPC, P1QB, P2QB, PKPC, P1PK, POULPC, P1POUL, P2POUL, DINC, P1Y, DV77ON)	1955-19	-31	-43	-52
FBP = F(C, BFPC, P1QB, P2QB, P3QB, PKPC, P1PK, POULPC, P1POUL, DINC)	1955-19	-36	-46	-53
FBP = F(C, BFPC, P1QB, P2QB, PKPC, P1PK, POULPC, P1POUL, P2POUL, DINC, DV77ON)	1955-19	-30	-42	-50
PPORK = F(C, BFPC, PKPC, P1PK, P2PK, POULPC, DINC)	1955-19	-59	-66	-71
PPORK = F(C, BFPC, PKPC, P1PK, POULPC, DINC, P1Y)	1955-19	-57	-64	-69
PPORK = F(C, BFPC, PKPC, P1PK, P2PK, POULPC, DINC, P1Y	1955-19	-57	-65	-71
PPORK = F(C, BFPC, PKPC, P1PK, P2PK, POULPC, P1POUL, P2POUL, DINC)	1955-19	-52	-61	-67
PPORK = F(C, BFPC, P1QB, PKPC, P1PK, POULPC, P1POUL, P2POUL, DINC, P1Y, DV77ON)*	1955-19	-37	-49	-58
PPORK = F(C, BFPC, P1QB, PKPC, P1PK, POULPC, P1POUL, P2POUL, DINC, DV77ON)	1955-19	-51	-61	-68

Table 7.1 (Continued)

MODEL SPECIFICATION	PERIOD	LOG-LIKELIHOOD	AIC	PPC
CHP = F(C, BFPC, PKPC, POULPC, P1POUL, DINC)	1955-1985	-50	-56	-60
CHP = F(C, BFPC, PKPC, POULPC, P1POUL, P2POUL, DINC)	1955-1985	-50	-57	-62
CHP = F(C, BFPC, PKPC, POULPC, P1POUL, P2POUL, P3POUL, DINC)	1955-1985	-48	-56	-61
CHP = F(C, BFPC, PKPC, POULPC, P1POUL, DINC, P1Y	1955-1985	-41	-48	-53
CHP = F(C, BFPC, PKPC, POULPC, P1POUL, P2POUL, DINC, P1Y)	1955-1985	-41	-49	-54
CHP = F(C, BFPC, PKPC, POULPC, P1POUL, P2POUL, P3POUL, DINC, P1Y)	1955-1985	-37	-46	-53
CHP = F(C, BFPC, P1QB, PKPC, POULPC, P1POUL, P2POUL, P3POUL, DINC, P1Y, DV77ON)	1955-1985	-35	-46	-54
CHP = F(C, BFPC, P1QB, PKPC, P1PK, POULPC, P1POUL, DINC, P1Y, DV77ON)	1955-1985	-35	-45	-52
CHP = F(C, BFPC, P1QB, PKPC, P1PK, POULPC, P1POUL, DINC, P1Y, DV77ON	1955-1985	-40	-50	-57
E. CONSTANT PARAMETER MODEL				
FBP = F(C, BFPC, PKPC, POULPC, DINC)	1955-1985	-72	-77	-81
PPORK = F(C, BFPC, PKPC, POULPC, DINC)	1955-1985	-66	-71	-75
CHP = F(C, BFPC, PKPC, CHPC, TKPC, DINC)	1955-1985	-55	-61	-65
TKP = F(C, BFPC, PKPC, CHPC, TKPC, DINC)	1955-1985	-59	-65	-69

The results also shows that the value of the log-likelihood function is larger for constant parameter price models which are estimated using more current time series data. Using data during the past 31 years without accounting for parameter variation reduces the value of the log-likelihood function by more than half.

Trend variables, T5576 and T77ON, were introduced to the constant parameter models to test for shifts in demand beginning 1977, the approximate starting period of parameter change as indicated by the recursive residual analysis. The models were estimated using two time periods: 1955-1985 and 1970-1985. The values of the AIC and PPC criteria of the augmented models indicate significant improvement in the goodness-of-fit and relative parsimony performance relative to the constant parameter price models which do not account for the shifts in demand.

Among the alternative specifications to approximate the shifts in demand for meat over time, the continuous varying parameter specification using Legendre polynomials have the best performance based on the AIC and PPC criteria. The model which allows gradual continuous variation in both the own-quantity and cross flexibilities with respect to pork and poultry and shift in the intercept starting in 1977 appear superior among all beef price models as evidenced by values of -42 and -50 for AIC and PPC, respectively. No significant improvement in the values of the AIC and PPC for this beef price model was achieved when the income flexibility was also allowed to change. AIC and PPC values for this models (equation 5.4.5 and 5.4.7) were -43 and -52, respectively. This may be explained by the insignificance of the legendre polynomial introduced in the income variable in the beef price equation after allowing for variations in the own-quantity and cross-quantity flexibilities.

Among the pork price model with Legendre polynomials, the model which allows all parameters to change over time and has an intercept shifter beginning in 1977 has the best goodness of fit and relative parsimony performance. The AIC and PPC criteria correspond to values of -49 and -58, respectively. The broiler price model which allows continuous variation of own-quantity, cross-quantity, and income flexibilities, including a shift in the intercept starting 1977 correspond to the highest values of both AIC and PPC at levels equal to -45 and -52, respectively.

In general, the discrimination among the price models based on the goodness of fit and relative parsimony performance measures provided consistent results. That is, the AIC and PPC criteria both indicated superior performance of price models which allow gradual continuous variation of all demand parameters and include a shift beginning in 1977.

7.4 Historical Simulation Results

Historical simulation involves the estimation of the endogenous variables in the model during the historical period. The purpose of this aspect of validation is to evaluate the ability of the model as a system to replicate the corresponding historical series. This section presents the results of the historical simulation of the U.S. livestock and poultry model.

The predictive ability of alternative specifications of parameter variation in the price models (also called inverse demand model) are compared. The tracking performance of the challenger model of hog supply presented in chapter 6 is compared with those of the defender base model of hog supply presented in chapter 3. The challenger model includes the effects of some aspects of structural change in the hog industry. This is carried out by introducing the trends in the physical relationships that are likely to be affected by the identified structural change.

The simulation runs from 1975 to 1985. The results of two simulation exercise are presented in this section. The first simulation includes the challenger model of hog supply (presented in chapter 6),the base model of the beef and poultry supply (discussed in chapter 3), and the selected continuous varying parameter models of prices (models with

Legendre polynomials selected based on the AIC and PPC criteria). The second simulation uses the defender base model of the hog, beef and poultry supply and price models with trend shifter variables (DVT73,DV73ON,DVT80,DV80ON) presented in chapter 3. The results of the simulation are summarized in Table 7.2 to Table 7.6. For each simulation, the values of percent errors of simulated values of endogenous variables are reported for each simulation year. Other measures of relative and absolute accuracy of simulated values are also reported.

Johnson and Rausser (1977) indicated some limitations of model validation based on ex-post data for the exogenous or predetermined variables. Since the errors in projecting the latter are not included in the ex-post estimates, the accuracy of tests based on ex-post predictions may be overstated. In this study, the individual equations are estimated using data up to 1985. Hence, ex-post forecasts are not generated. However, projections for 1986 may be compared with the 1986 estimates from USDA statistical reports.

The ex-post (historical) performance of the model is evaluated based on relative and absolute accuracy measures for each endogenous variables. In general, the predictive ability of the model is quite good as indicated by the low percent errors of simulated values for almost all endogenous variables. Historical simulation results indicate the price variables to be well predicted by models which accounts for parameter variation over time.

Overall, the values of the absolute and relative accuracy measures indicate a better performance of the pork supply model which considers changes in biological and/or physical relationships (presented in Chapter 6, referred as PORKSM2 in the following discussion) over the base model (presented in Chapter 3). Compared with the base price models which only allow abrupt shifts in demand as measured by the trend shifter variables, more accurate results of simulated values are given by the price models which allow for gradual continuous variation of the demand flexibilities. A significant improvement in replicating the historical series of hog price and pork production was achieved by using PORKSM2. This can be seen in the lower percent error of estimated values during each simulation year. The root squared error of simulated values of both variables estimated using PORKSM2 were half of those estimated from the base hog supply model. Also, by using the PORKSM2, the proportion of error in estimated hog prices due to bias was reduced from .218 to .012, representing more than 90 percent reduction.

A significant improvement in the accuracy of simulated values of sows farrowing in the fall was also realized by using the PORKSM2 model. The root squared error, for instance, declined from 3400 to 222.9, reducing the proportion of error due to bias from .996 to 0.02. Also, U(2) declined from 6.39 to .381, indicating a superior performance of the PORKSM2 model over a naive no-change model. The mean of the absolute value of the errors decreased from 3000 thousand head to 164 thousand head. In both simulations, the same specification of the beef supply model was used. It is interesting to note that the predictive performance of the beef supply variables is almost the same in both simulations. However, a slight imrovement in the accuracy of simulated values of beef cow numbers, fed-beef supply, and non-fed beef quantity is achieved by using the PORKSM2 model.

In the case of the poultry sector variables, no significant improvement in predictive performance was realized by using the continuous varying parameter models. Values of the percent error for each simulation year indicate more accurate predictions in some years and less accurate in others. Overall, the values of both relative and absolute accuracy measures indicate the same performance of the broiler and turkey price models with trend shifters and those with continuous varying parameters.

Within the PORKSM2 pork supply model, alternative specification of the pigs per litter equation are evaluated. Simulation results indicate that a linear trend specification of pigs per litter has validation problems, while the flexible trend and dummy variable specifications perform relatively well in tracking the historical series.

7.5 Projections

The second stage of model evaluation involves the use of the model as a system in generating ex-post and ex-ante forecasts of endogenous variables. Ex-post forecasts for 1986 are generated using historical values for exogenous variables. The ex-post forecast of endogenous variables are compared to actual data in 1986. Ex-ante forecasts are generated using forecast values of exogenous and predetermined variables and the model is simulated beyond the estimation period.

The model is in large part recursive. Supply is predetermined while demand responds to current information, including quantities supplied. To the extent that the model is recursive, single equation bias and inconsistency in parameter estimates are minimized. Simulation of the model is carried out using the GSIM simulation procedure developed in the Department of Agricultural Economics (Wolf,1983). The algorithm follows the Gauss-Siedel method of iteration to obtain a solution to a set of simultaneous equations.

Evaluation of the forecasting ability of a model is useful for both predictive purposes and policy analysis. Forecasts may be used to determine and compare the impact of changes in some controllable exogenous variables or the effects of changes in the estimated parameters on the values of the endogenous variables.

7.5.1 Assumptions on Key Exogenous Variables

The assumed values of the important exogenous variables during the projection period are given in Table 7.8. Population of the U.S. was projected to increase from 237 million in 1985 to 254 million in 1993. Real per capita disposable income was projected to increase by 2.0 percent from 1985 to 1986 and by 2.5 percent per year in 1987-1993. For the baseline projection, corn and soymeal prices are held constant during the projection years at $2.0 per bushel and $8.8/cwt., respectively. The effects of changes in feed prices may be then be evaluated and compared with the baseline figures. Also, in the baseline projection, the consumer price index is held fixed at its 1985 level (3.22 percent).

TABLE 7.8

Projected Values of Exogenous Variables

Year	Civilian Population	Disposable Income Per Person, Real	Interest Rate
	(POPUS) millions	(DPCIT) $/person	(INTT) percent
1986	239	3710	10.9
1987	241	3800	10.3
1988	243	3890	10.0
1989	245	3990	9.8
1990	248	4090	9.8
1991	250	4190	9.8
1992	252	4300	9.8
1993	254	4410	9.8

7.5.2 Projections of Endogenous Variables

The version of the livestock and poultry model which includes PORKSM2 and meat price models with varying parameters are used in generating projections of U.S. livestock production and prices.

As shown in Figure 7.1, beef cow numbers will fall to 33.06 million head in 1987 before increasing to its next peak around 1992 at about 38.461 million head. This next peak level of beef cow numbers is about 16 percent lower than the 1975 reported beef cow numbers.

Fed and non-fed beef supply are projected to continue to decline from their 1985 levels up to 1989 and then increase starting in 1990 reaching their next peak

levels in 1993. At this next peak, fed beef supply is projected to be about 1.9 percent lower than the previous 1985 peak. The projected 1993 level of non-fed beef supply, on the other hand, is about 12.6 percent lower than the last peak level in 1984. The projections show that the corresponding predictions of per capita beef supply in 1989 will be at its lowest since 1962. Although the projected per capita supply available for consumption of beef and pork are expected to trend down over the next 7 years, total meat per capita supply is expected to stay in the same range due to broiler and turkey per capita supply being projected to continue growing at the same rate observed over the past 20 years.

Fed Choice steer prices in constant 1985 dollars are projected to increase up to 1988, reaching a level of a little above $80, as per capita supply of beef decreases during this period. The above projections were estimated under very low assumed real corn and soymeal prices over the entire period, and hence, are maybe on the higher side.

Sows farrowings in the spring in 1986 is estimated to be 5424 thousand head, down 2.4 percent from 1985. This is consistent with the projected cutbacks in herd size since 1983 due to the continued poor returns and financial stress beginning in early 1980s. Improvement in producers returns is projected 1987 as indicated by higher hog prices and very low corn prices projected during this period. With the projected increase in producers returns in 1987, spring farrowings are projected to increase from the 1986 level and reach a peak at 6486 thousand head in 1988. Fall farrowings, likewise are projected to increase and reach a peak level of 6716 thousand head in 1988.

Pork production is then projected to reach its next peak in 1989, reaching 16.591 billion pounds. The projected 1989 peak level of pork production is up only 1 percent from the last peak in 1980. The resulting price of hogs in 1989 is projected to reach a record low of $39 in constant 1985 dollars. With the projected decline in hog prices and the assumed constant level of corn prices, sows farrowing is projected to continue to decline reaching 5.8 billion head in both spring and fall in 1990, down 8.1 percent from the previous year peak of 6.311 billion head.

The decline in spring and fall sows farrowing is projected to continue to 1993 as hog prices continue to remain low during the early 1990s. Total commercial pork production is estimated to be 14.128 billion pounds in 1986, down 4 percent from 1985. Commercial hog slaughter is estimated to reach 81.042 billion head, also down 4 percent from 1985. Average dressed weight is estimated at 174 in 1985. These set of estimates of hog supply variables for 1986 are observed to be very close to the 1986 estimates published by USDA in the November, 1986 Livestock and Poultry Situation and Outlook.

Table 7.2 Percent Errors of Simulated Values for 1975-1985 and Absolute and Relative Accuracy of Simulated Values Using PORKSM2 of Pork Production and Selected Inverse Demand Models with Varying Parameters

YEAR/ERRORS	BFCOWT	SOWFST	SOWFFT	PORKQT	FBEFQT	NFBFQT
1975	-5.14	5.35	4.15	1.41	6.91	-19.50
1976	-0.19	-0.45	1.09	-1.69	0.15	3.35
1977	0.70	-0.03	0.79	1.12	0.28	2.69
1978	1.62	2.48	-3.26	0.97	-5.61	10.90
1979	3.10	-1.45	-3.61	·0.20	0.70	33.10
1980	4.52	-3.43	-1.49	0.75	-4.27	7.81
1981	0.14	-2.22	-0.63	-0.36	-6.46	6.67
1982	-0.18	1.84	-1.04	0.81	0.67	8.22
1983	1.71	0.03	5.22	-1.77	2.20	4.89
1984	-1.00	2.22	1.54	0.51	0.26	1.57
1985	1.90	-3.66	-7.16	-2.72	-4.57	3.46
MEAN ERROR	224.00	-7.29	-31.60	-14.00	-174.00	190.00
MEAN OF ABSOLUTE ERROR	704.00	125.00	164.00	155.00	534.00	417.00
MEAN OF PERCENT ERROR	0.71	0.06	-0.40	-0.07	-0.89	5.74
MEAN OF ABSOLUTE PERCENT ERROR	1.79	2.11	2.73	1.12	2.92	9.29
SQUARED MEAN ERROR	50164.00	53.18	997.62	195.39	30401.00	36022.00
ROOT SQUARED ERROR	1050.20	165.88	222.91	203.96	771.00	613.30
PROPORTION DUE TO						
BIAS	0.04	0.00	0.02	0.00	0.05	0.10
SYSTEMATIC ERROR	0.21	0.25	0.00	0.00	0.19	0.07
RANDOM ERROR	0.75	0.75	0.98	1.00	0.76	0.83
THEIL-U COEFFICIENTS						
U(1)	0.012	0.01	0.02	0.01	0.02	0.06
U(2)	0.571	0.24	0.38	0.17	0.67	0.92

PORKSM2 refers to the model of Pork Production with physical and biological relationships specified as restrictions.

Table 7.3 Percent Errors of Simulated Values for 1975-1985 and Absolute and Relative Accuracy of Simulated Values Using PORKSM2 of Pork Production and Selected Inverse Demand Models with Varying Parameters

YEAR/ERRORS	PORKPT	FBEFPT	BFCOWP	CHIKPT	TURKPT	EGGPT
1975	-1.70	-2.15	23.70	-1.32	7.35	1.06
1976	1.83	-3.25	-18.50	-8.61	-8.87	-12.90
1977	-0.00	7.55	2.80	4.65	6.53	-3.90
1978	-1.11	5.93	3.07	7.03	-0.66	13.90
1979	-3.13	-5.89	-10.60	-4.16	-12.10	-1.17
1980	-0.63	5.78	3.11	-4.70	1.16	-3.00
1981	9.13	14.30	11.00	4.80	3.61	-5.44
1982	-2.22	-3.71	-4.95	11.20	-2.69	-10.70
1983	-9.21	-7.07	12.40	-2.47	6.83	-3.71
1984	3.58	3.83	4.57	2.40	1.82	9.67
1985	15.60	13.10	1.01	20.50	9.36	32.60
MEAN ERROR	0.12	0.53	-0.05	0.23	0.12	0.06
MEAN OF ABSOLUTE ERROR	0.73	1.53	1.47	0.72	0.94	2.04
MEAN OF PERCENT ERROR	1.10	2.58	0.18	2.66	1.12	1.50
MEAN OF ABSOLUTE PERCENT ERROR	4.38	6.60	9.48	6.53	5.54	8.92
SQUARED MEAN ERROR	0.01	0.29	0.00	0.05	0.01	0.00
ROOT SQUARED ERROR	1.08	1.88	1.97	0.94	1.29	2.92
PROPORTION DUE TO						
BIAS	0.01	0.08	0.00	0.06	0.01	0.00
SYSTEMATIC ERROR	0.02	0.02	0.06	0.00	0.02	0.00
RANDOM ERROR	0.97	0.90	0.94	0.94	0.97	1.00
THEIL-U COEFFICIENTS						
U(1)	0.02	0.03	0.05	0.04	0.03	0.05
U(2)	0.32	0.53	0.61	0.65	0.46	0.92

PORKSM2 refers to the model of Pork Production with physical and biological relationships as restrictions

Table 7.4 Percent Errors of Simulated Values for 1975-1985 and Absolute and Relative Accuracy of Simulated Values using PORKSM2 of Pork Production and Selected Inverse Demand Models with Varying Parameters

YEAR/ERRORS	PPLF(D)	PPLF(T)	PPLS(D)	PPLS(T)	TPC	GRTF	GRTS
1975	-0.21	1.21	0.21	1.80	4.25	5.13	-0.04
1976	-0.52	1.01	-2.09	-0.22	-0.65	-1.79	-0.00
1977	-0.21	1.49	0.07	2.37	0.20	0.02	0.04
1978	-0.31	1.75	0.54	3.49	-0.43	2.29	0.01
1979	0.40	2.83	0.22	3.82	-1.95	-1.12	-0.06
1980	0.37	1.88	0.35	1.32	-1.70	-2.62	-0.04
1981	-0.76	-0.20	-0.79	-0.59	-1.46	-2.12	-0.02
1982	-0.15	-0.39	0.64	0.16	0.41	1.73	0.02
1983	0.81	-0.26	-0.68	-1.85	1.00	-3.07	0.21
1984	0.16	-1.40	0.84	-0.75	1.02	0.75	-1.64
1985	-0.43	-3.28	-0.49	-3.23	-5.00	-5.72	-0.86
MEAN ERROR	-0.01	0.030	-0.008	0.03	-452.00	-9.81	-4.42
MEAN OF ABSOLUTE ERROR	0.03	0.100	0.046	0.13	1400.00	50.60	5.64
MEAN OF PERCENT ERROR	-0.08	0.420	-0.110	0.57	-0.39	-0.59	-0.22
MEAN OF ABSOLUTE PERCENT ERROR	0.39	1.430	0.630	1.78	1.64	2.40	0.27
SQUARED MEAN ERROR	0.00003	0.000	0.000	1.00	2E+05	96.20	19.57
ROOT SQUARED ERROR	0.03600	0.130	0.066	0.16	2E+03	66.60	12.70
PROPORTION DUE TO							
BIAS	0.02500	0.044	0.016	0.05	0.04	0.02	0.12
SYSTEMATIC ERROR	0.00900	0.574	0.000	0.54	0.13	0.19	0.04
RANDOM ERROR	0.96600	0.382	0.984	0.40	0.82	0.78	0.84
THEIL-U COEFFICIENTS							
U(1)	0.00200	0.030	0.004	0.04	0.01	0.01	0.00
U(2)	0.38100	0.530	0.415	0.65	0.23	0.14	0.02

PORKSM2 refers to the model of Pork Production with physical and biological relationships as restrictions. The beef and poultry models presented in chapter 3 are used in the simulation.

Table 7.5 Percent Errors of Simulated Values for 1975-1985 and Absolute and Relative Accuracy of Simulated Values Using PORKSM2 of Pork Production and Selected Inverse Demand Models with Varying Parameters

YEAR/ERRORS	SLBGS	SLBGF	SSS	SSF	TSLHG	ADWHG
1975	-5.66	1.21	0.21	1.80	4.25	5.13
1976	-7.20	1.01	-2.09	-0.22	-0.65	-1.79
1977	-2.03	1.49	0.07	2.37	0.20	0.02
1978	1.62	1.75	0.54	3.49	-0.43	2.29
1979	0.88	2.83	0.22	3.82	-1.95	-1.12
1980	-1.45	1.88	0.35	1.32	-1.70	-2.62
1981	-2.20	-0.20	-0.79	-0.59	-1.46	-2.12
1982	-1.49	-0.39	0.64	0.16	0.41	1.73
1983	-4.33	-0.26	-0.68	-1.85	1.00	-3.07
1984	-2.86	-1.40	0.84	-0.75	1.02	0.75
1985	-2.07	-3.28	-0.49	-3.23	-5.00	-5.72
MEAN ERROR	-936.00	0.03000	-0.00830	0.03800	-452.00000	-9.81000
MEAN OF ABSOLUTE ERROR	1.10E+03	0.10000	0.04600	0.13000	1400.0000	50.60000
MEAN OF PERCENT ERROR	-2.43	0.42000	-0.11000	0.57000	-0.39000	-0.59000
MEAN OF ABSOLUTE PERCENT ERROR	2.89	1.43000	0.63000	1.78000	1.64000	2.40000
SQUARED MEAN ERROR	8.8E+05	0.00080	0.00007	1.00140	2.00E+05	96.20000
ROOT SQUARED ERROR	1329.00	0.13000	0.06600	0.16800	2050.7000	66.60000
PROPORTION DUE TO						
BIAS	0.50	0.04400	0.01600	0.05100	0.04900	0.02200
SYSTEMATIC ERROR	0.10	0.57400	0.00000	0.54900	0.13000	0.19400
RANDOM ERROR	0.40	0.38200	0.98400	0.40000	0.82100	0.78500
THEIL-U COEFFICIENTS						
U(1)	0.02	0.0300	0.00400	0.04000	0.01000	0.01400
U(2)	0.38	0.5300	0.41500	0.65000	0.23000	0.14100

PORKSM2 refers to the model of Pork Production with physical and biolgical relationships specified as restrictions. Models of beef and poultry production presented in Chapter 3 are used in the simulation.

Table 7.6 Percent Errors of Simulated Values for 1975-1985 and Absolute and Relative Accuracy of Simulated Values Using Base Model

YEAR/ERRORS	BFCOWT	SOWFST	SOWFFT	PORKQT	FBEFQT	NFBFQT
1975	-5.14	0.12	67.80	2.72	6.91	-19.50
1976	-0.20	-1.66	56.90	-2.03	0.05	3.96
1977	0.76	3.81	59.90	4.49	0.27	4.04
1978	1.62	1.43	49.40	4.51	-5.61	10.90
1979	3.10	-1.33	42.60	0.43	0.70	33.10
1980	4.52	-0.90	50.10	0.41	-4.27	7.81
1981	0.14	-2.32	49.40	-2.58	-6.51	7.19
1982	-0.19	3.85	61.00	2.04	0.80	8.30
1983	1.76	-1.47	57.10	-4.37	2.20	5.35
1984	-1.24	4.03	58.30	0.08	0.54	-0.02
1985	1.90	0.49	65.40	-2.90	-4.39	3.00
MEAN ERROR	220.00	27.00	3.00E+03	16.40	-167.00	194.00
MEAN OF ABSOLUTE ERROR	716.00	117.00	3.00E+03	333.00	536.00	422.00
MEAN OF PERCENT ERROR	0.70	0.55	56.20	0.25	-0.85	5.83
MEAN OF ABSOLUTE PERCENT ERROR	1.83	1.95	56.20	2.42	2.93	9.38
SQUARED MEAN ERROR	48223.00	730.00	1.10E+07	268.72	28050.00	37792.00
ROOT SQUARED ERROR	1056.00	153.00	3400.00	437.57	869.90	618.00
PROPORTION DUE TO						
BIAS	0.04	0.03	1.00	0.00	0.05	0.09
SYSTEMATIC ERROR	0.20	0.06	0.00	0.03	0.19	0.06
RANDOM ERROR	0.76	0.91	0.00	0.97	0.76	0.84
THEIL-U COEFFICIENTS						
U(1)	0.01	0.01	0.22	0.01	0.02	0.06
U(2)	0.57	0.22	0.39	0.37	0.67	0.43

Base Model refers to the model presented in chapter 3.

Table 7.7 Percent Errors of Simulated Values for 1975-1985 and Absolute and Relative Accuracy of Simulated Values Using Base Model

YEAR/ERRORS	PORKPT	FBEFPT	BFCOWP	CHIKPT	TURKPT	EGGPT
1975	-4.28	-2.15	23.00	-1.64	6.93	0.50
1976	0.36	3.23	-18.80	-12.30	-8.72	-12.91
1977	-2.74	7.51	0.32	3.62	5.72	-6.21
1978	-5.58	5.93	1.81	6.92	-1.67	12.30
1979	-8.34	-5.89	-10.70	-7.93	-12.20	-1.31
1980	2.73	5.78	3.20	-6.62	1.26	-2.87
1981	10.40	14.70	12.40	0.52	4.93	-3.94
1982	-11.90	-4.81	-7.10	1.52	-3.97	-12.50
1983	-8.97	-7.51	-11.50	-3.50	8.54	-1.67
1984	-2.42	4.45	5.70	2.19	2.31	12.70
1985	-0.89	12.90	1.63	9.18	9.88	33.50
MEAN ERROR	-0.63	0.52	-0.11	-0.12	0.11	0.04
MEAN OF ABSOLUTE ERROR	1.03	1.58	1.46	0.60	1.01	2.09
MEAN OF PERCENT ERROR	-2.88	2.52	-0.16	-0.73	1.18	1.59
MEAN OF ABSOLUTE PERCENT ERROR	5.33	6.81	9.45	5.09	6.01	9.13
SQUARED MEAN ERROR	0.39	0.27	0.01	0.01	0.01	0.00
ROOT SQUARED ERROR	1.35	1.92	1.99	0.83	1.31	3.00
PROPORTION DUE TO						
BIAS	0.22	0.07	0.00	0.02	0.01	0.00
SYSTEMATIC ERROR	0.01	0.02	0.06	0.01	0.01	0.00
RANDOM ERROR	0.77	0.90	0.93	0.97	0.98	1.00
THEIL-U COEFFICIENTS						
U(1)	0.03	0.04	0.05	0.03	0.03	0.05
U(2)	0.41	0.54	0.61	0.37	0.47	0.95

Base Model refers to the model presented in chapter 3.

With the projected decline in sows farrowing beginning in 1989, pork production is predicted to decline in 1990 and stabilize during 1991-93. Pigs per litter in spring and fall 1986 are estimated to be 7.67 and 7.71, respectively. These are slightly above the record 7.64 and 7.67 for spring and fall litter size set in 1985. The increase in pigs per litter in previous years was in part due to the development of cross bred gilts for the breeding herd and the improvement in management practices and standards in the hog industry.

The flexible trend specification of the pigs per litter equation assumes the continuation of these factors, hence, projections generated from this equation shows litter size continually increasing, reaching a level of 8 pigs per litter during the early 1990s. The linear trend equation of litter size, however, results in less optimistic projections of pigs per litter. Using this latter specification will result in 7.4 pigs per litter during 1986-1990 and about 7.5 in 1991-1993.

Poultry production is expected to continue expanding. Production increases in broilers and turkeys are projected due to high producer returns, expectations of lower red meat supply and the projected continuation of the stronger substitutability of poultry for red meat. Poultry prices are expected to advance as strong demand for poultry

Figure 7.1

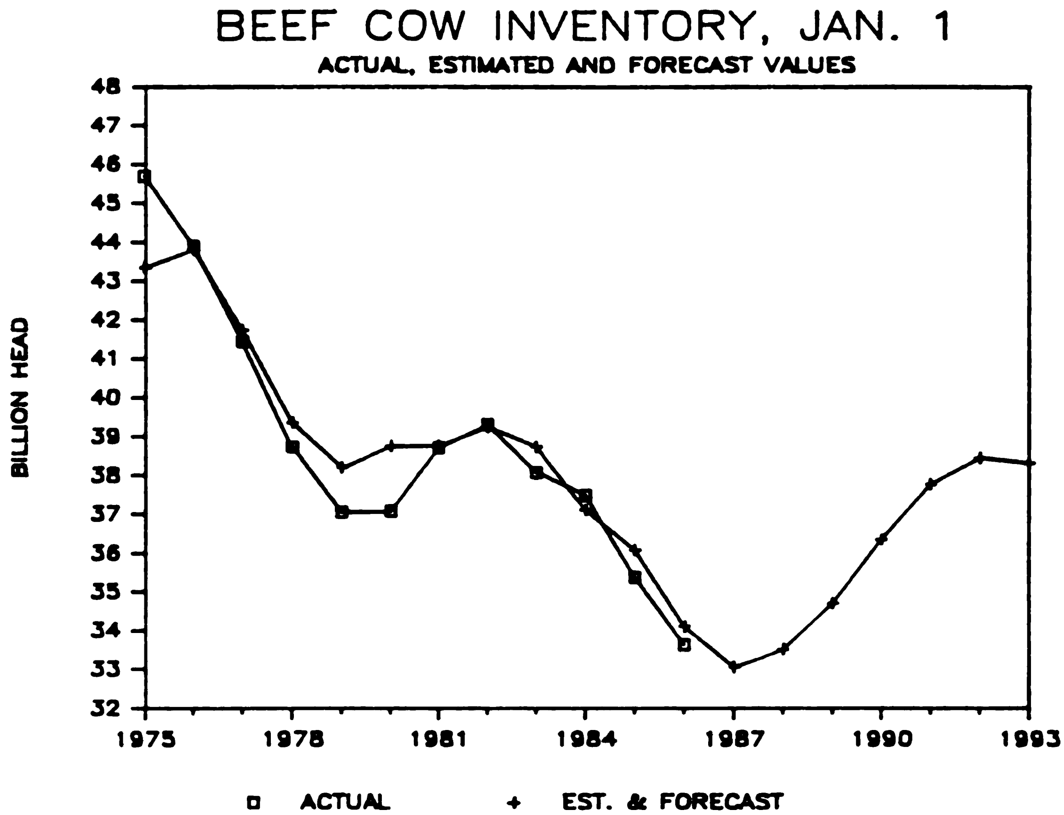
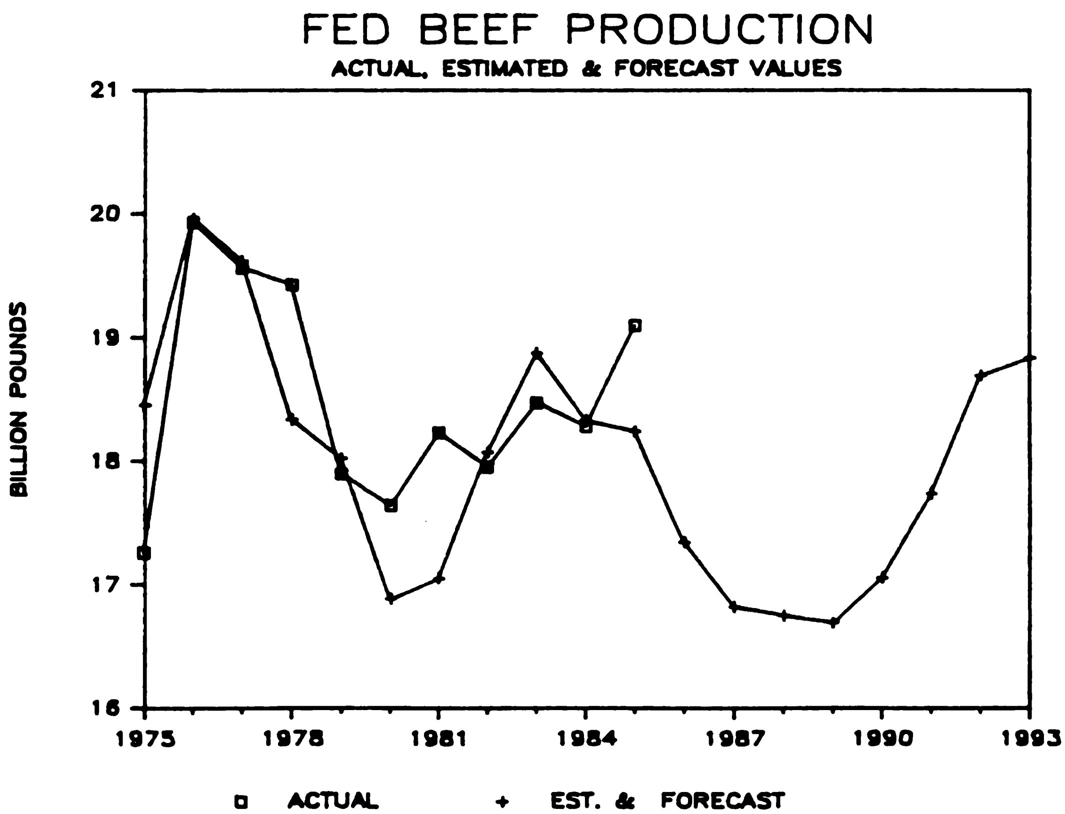


Figure 7.2



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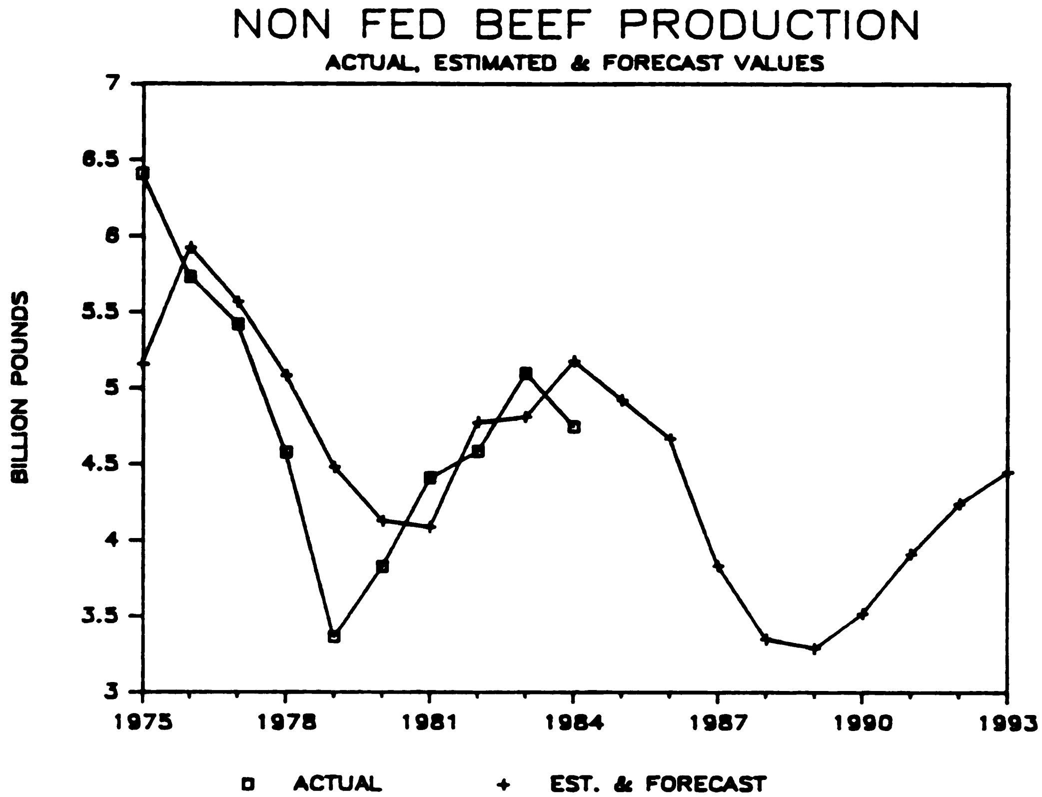

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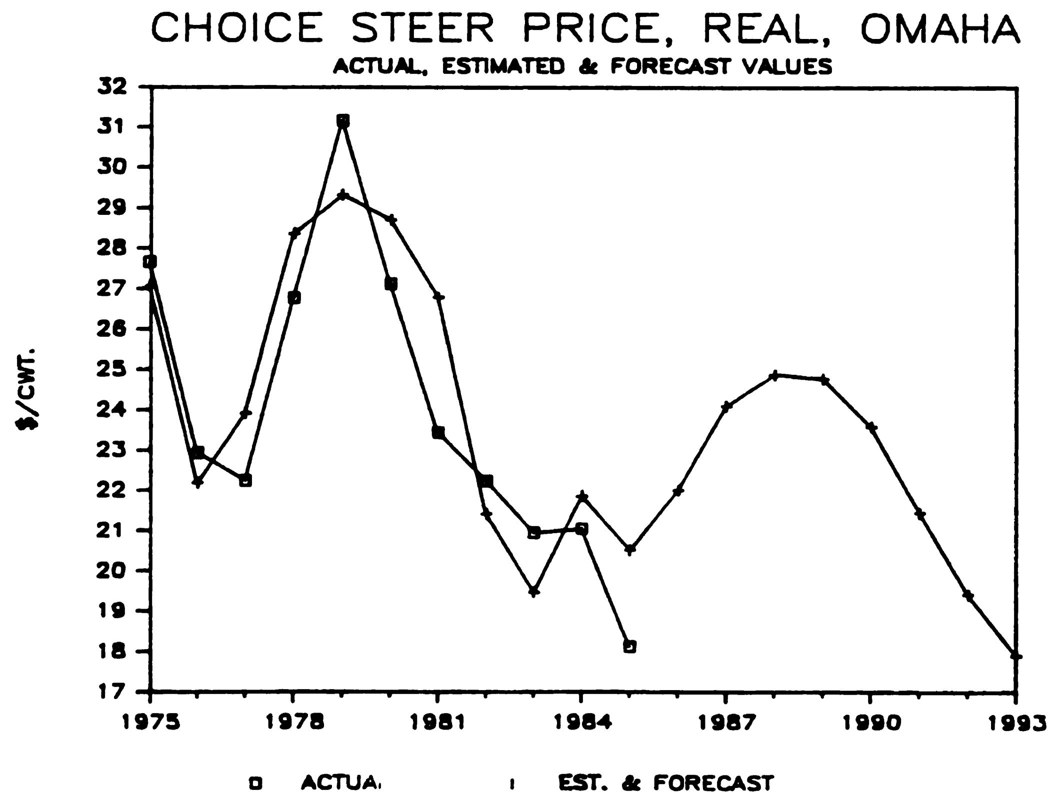

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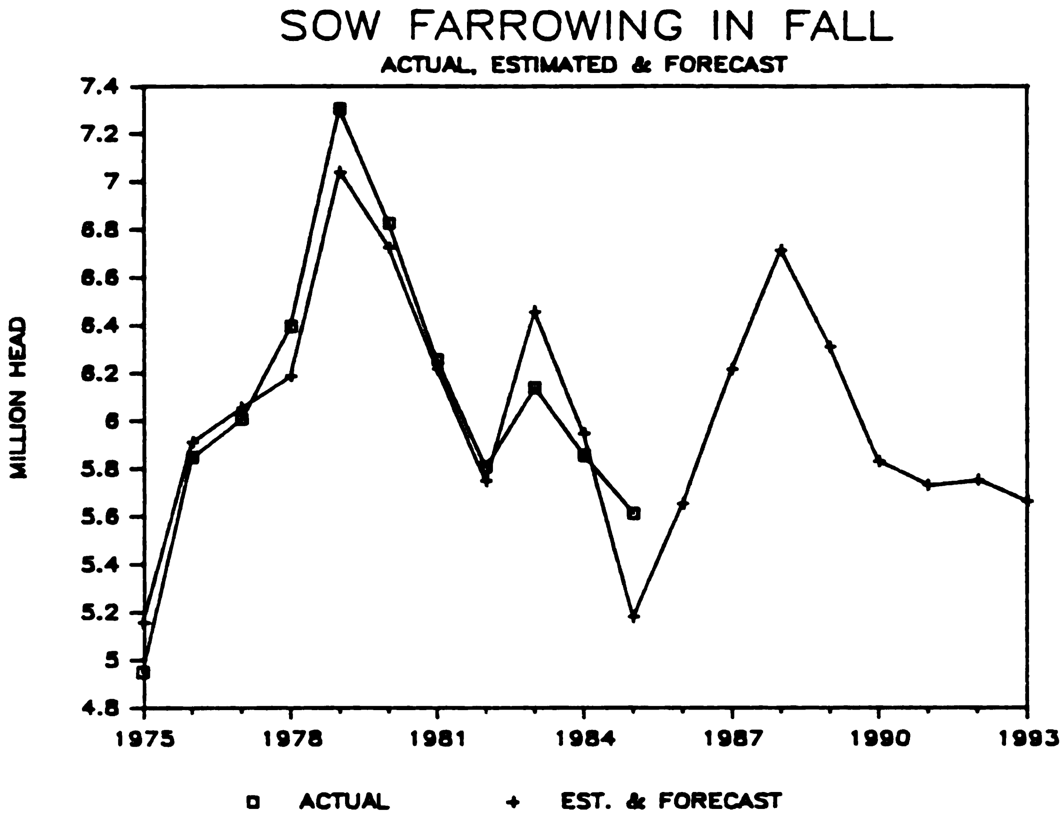

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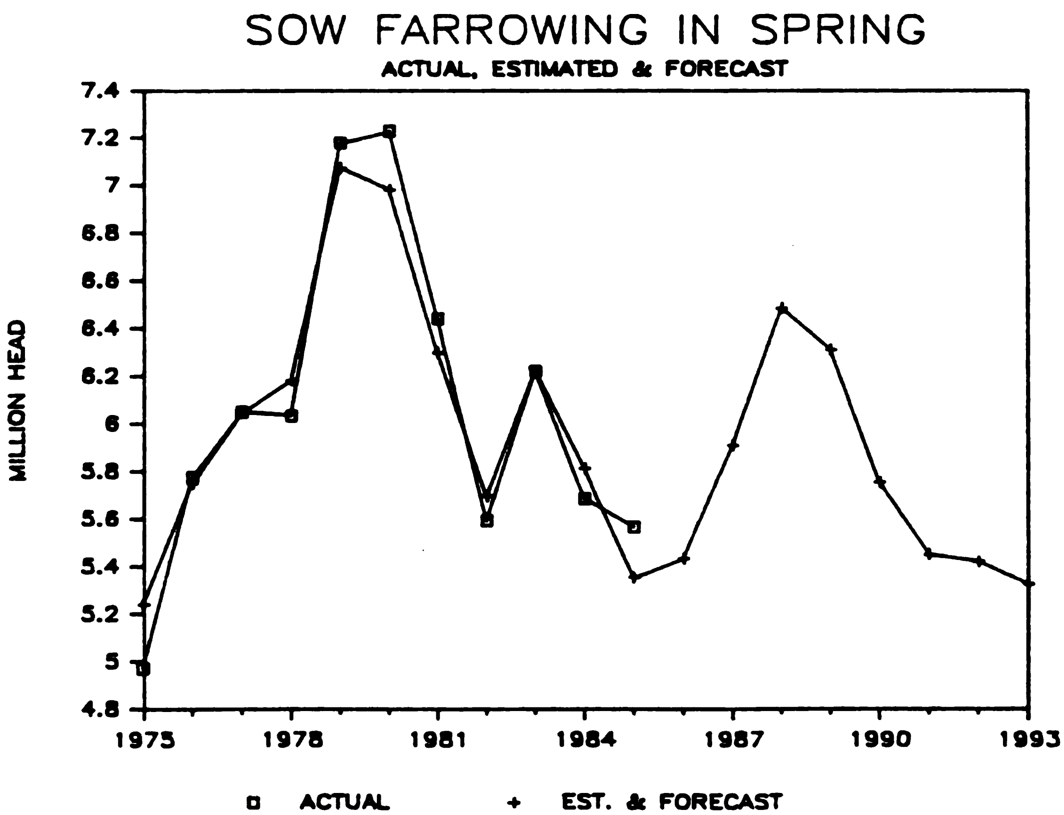

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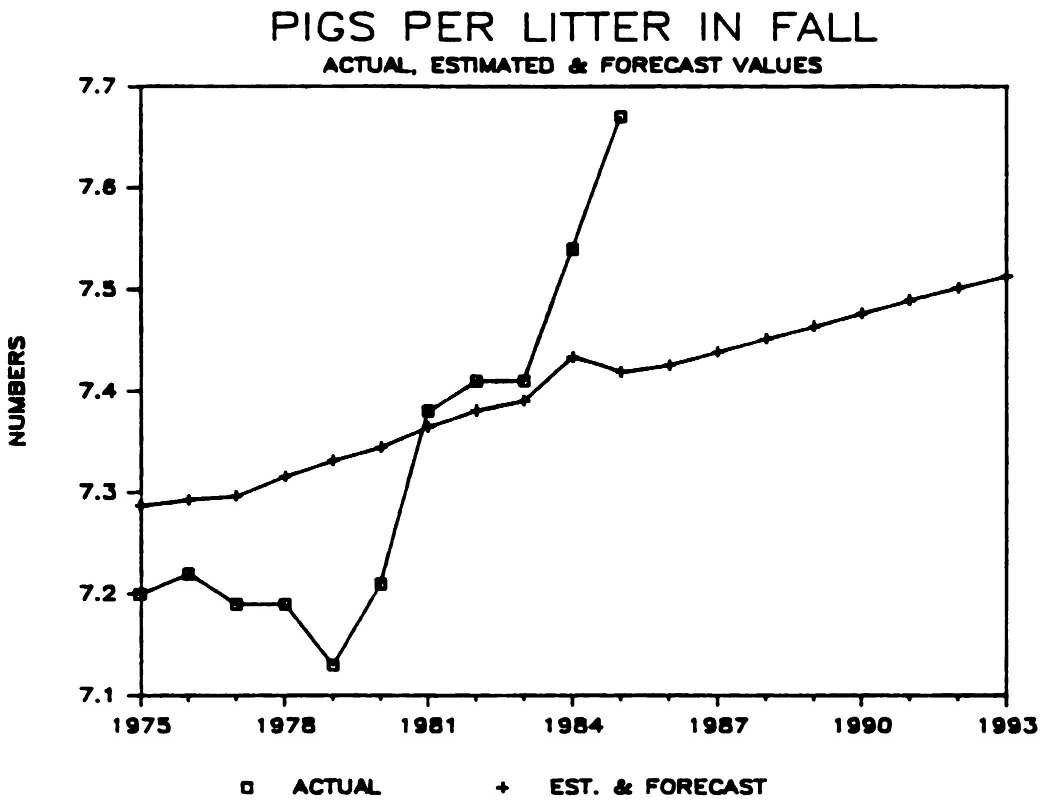

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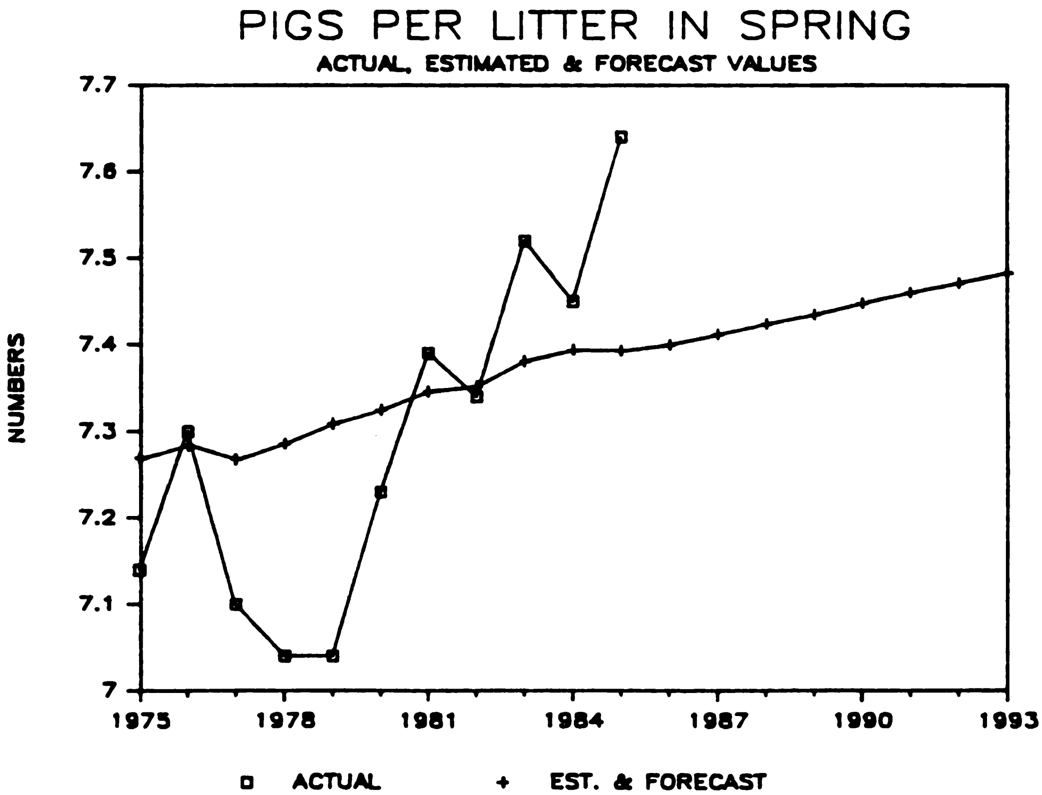

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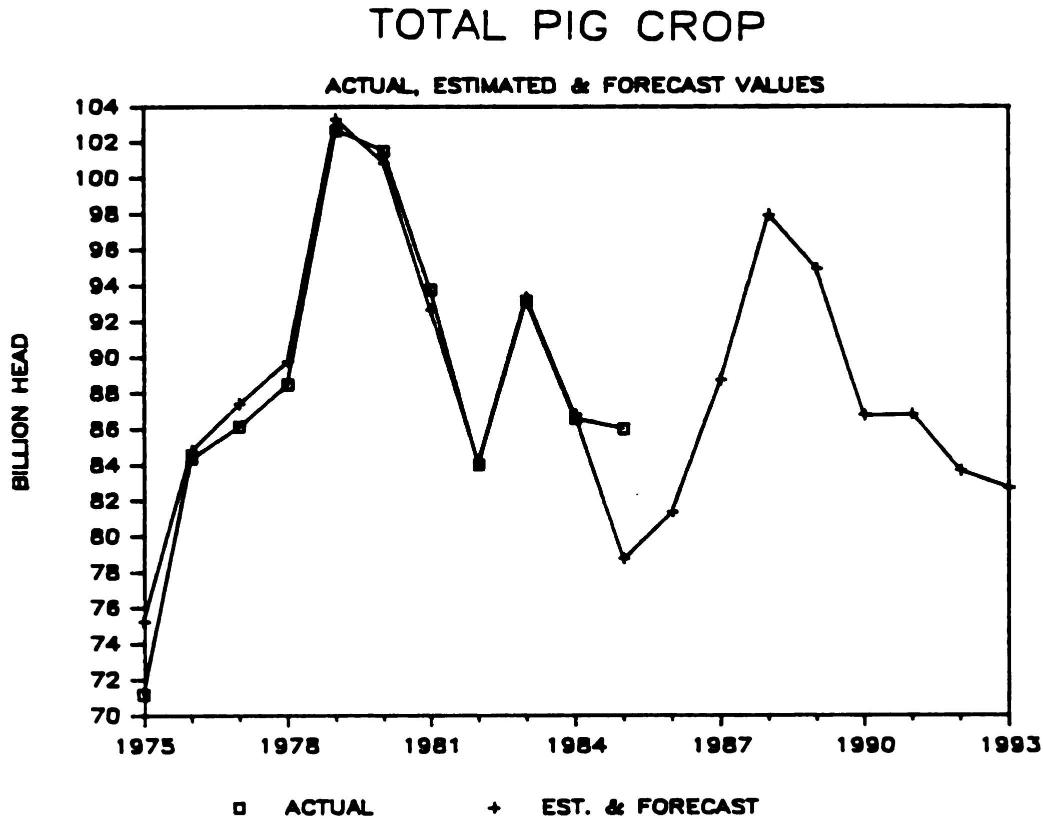

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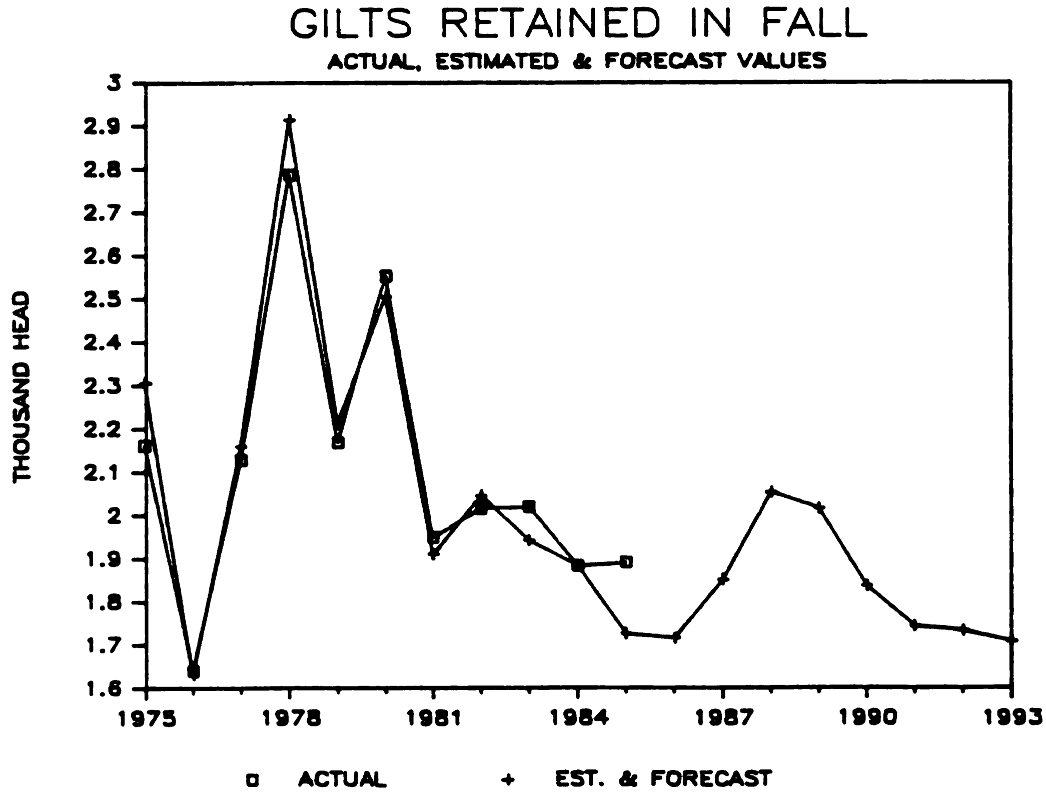


Figure 7.11

GILTS RETAINED IN SPRING

ACTUAL, ESTIMATED & FORECAST VALUES

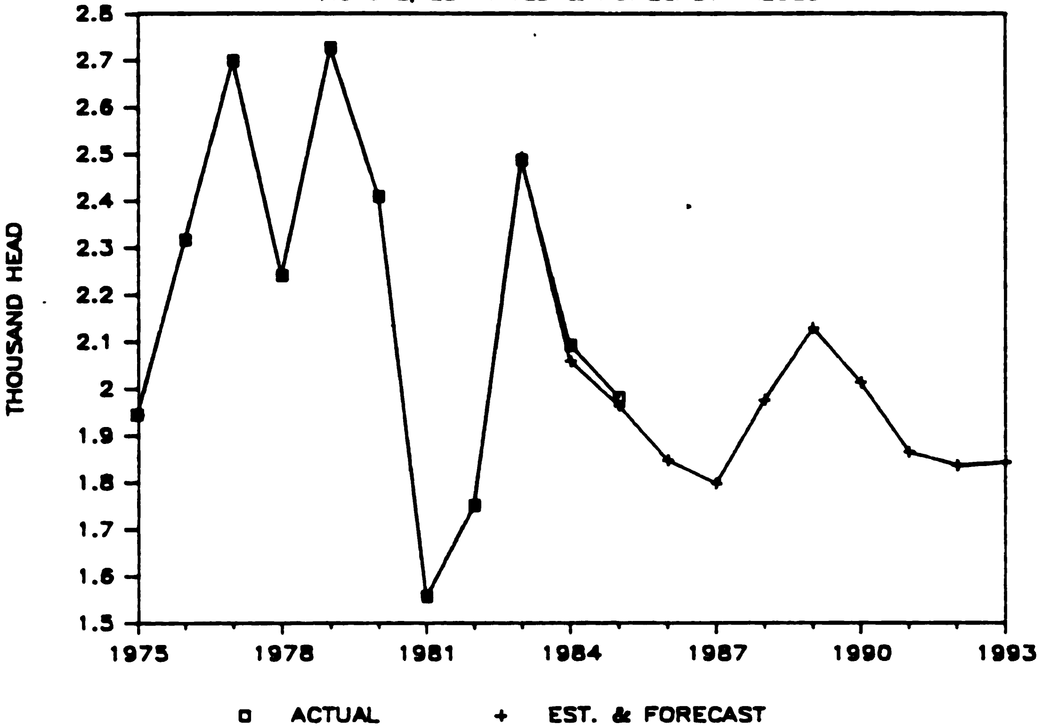
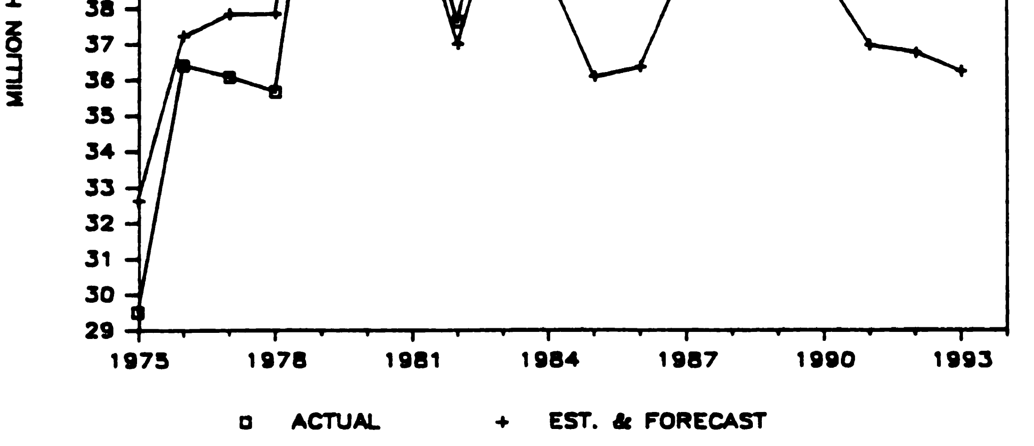


Figure 7.12

SLAUGHTER OF BARROW AND GILTS, FALL

ACTUAL, ESTIMATED & FORECAST VALUES



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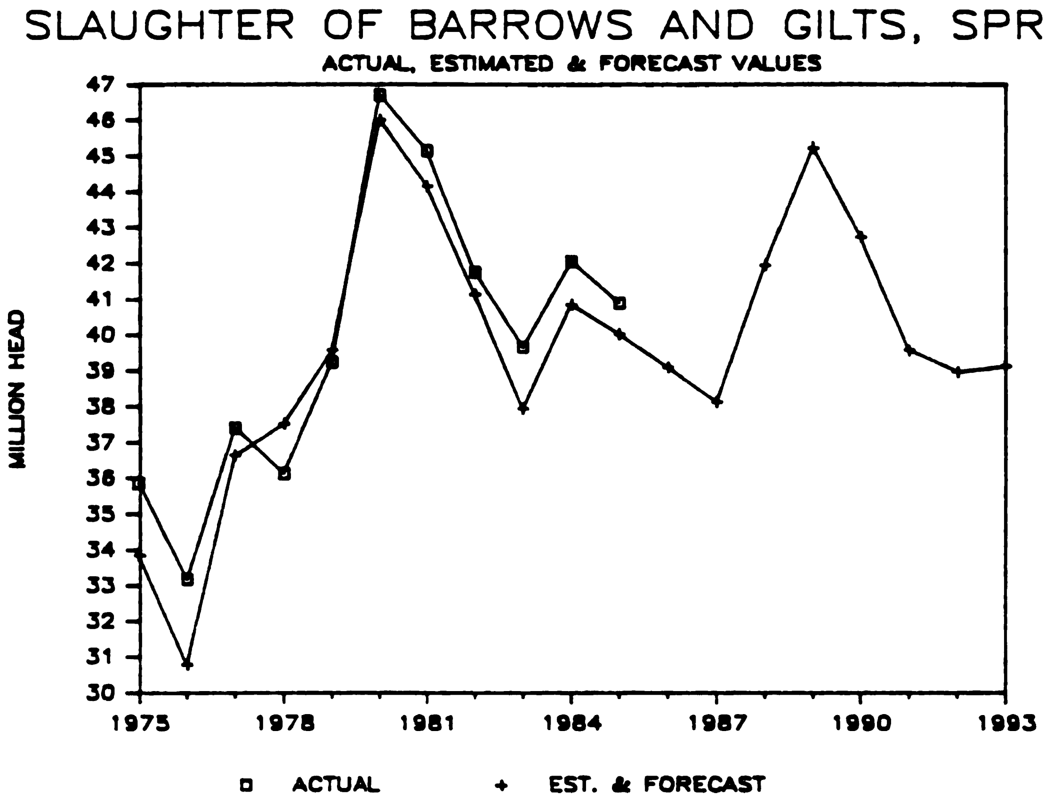

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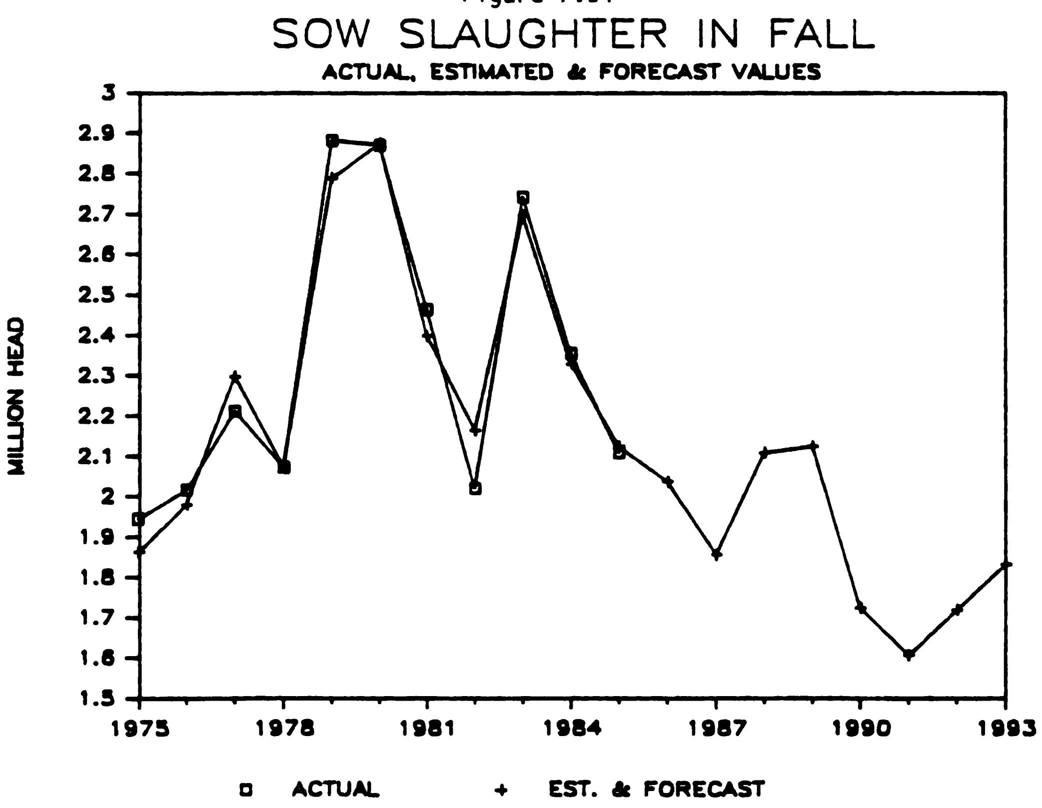

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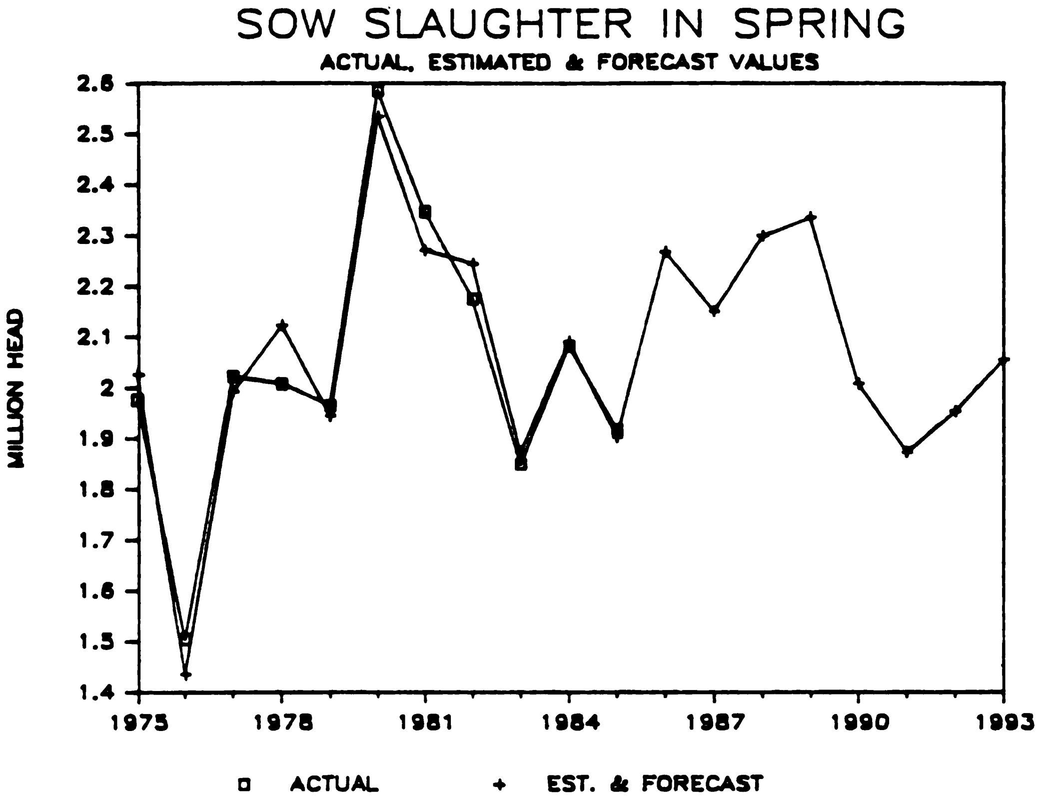

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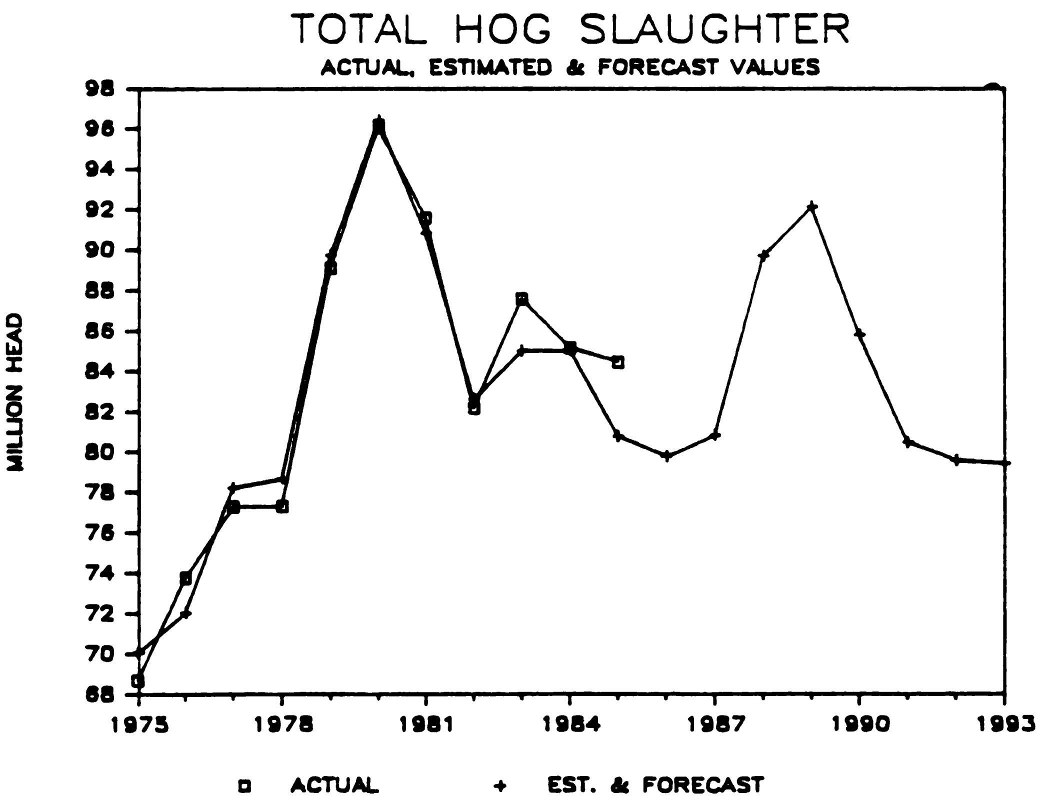

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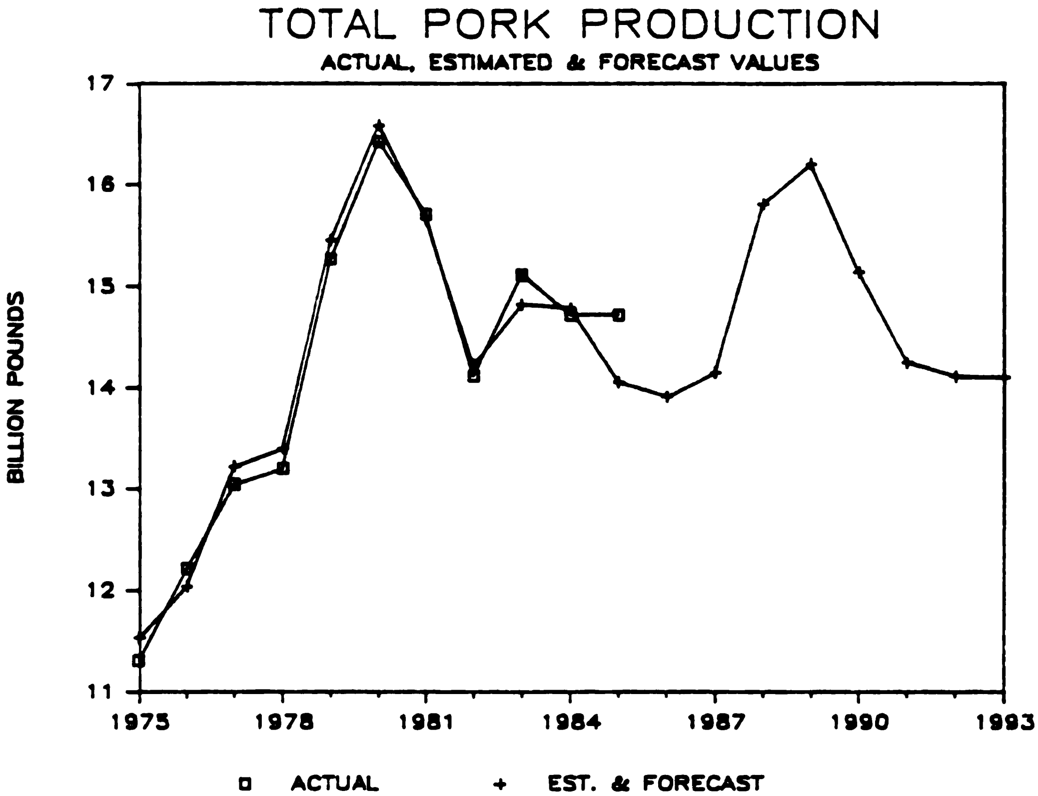

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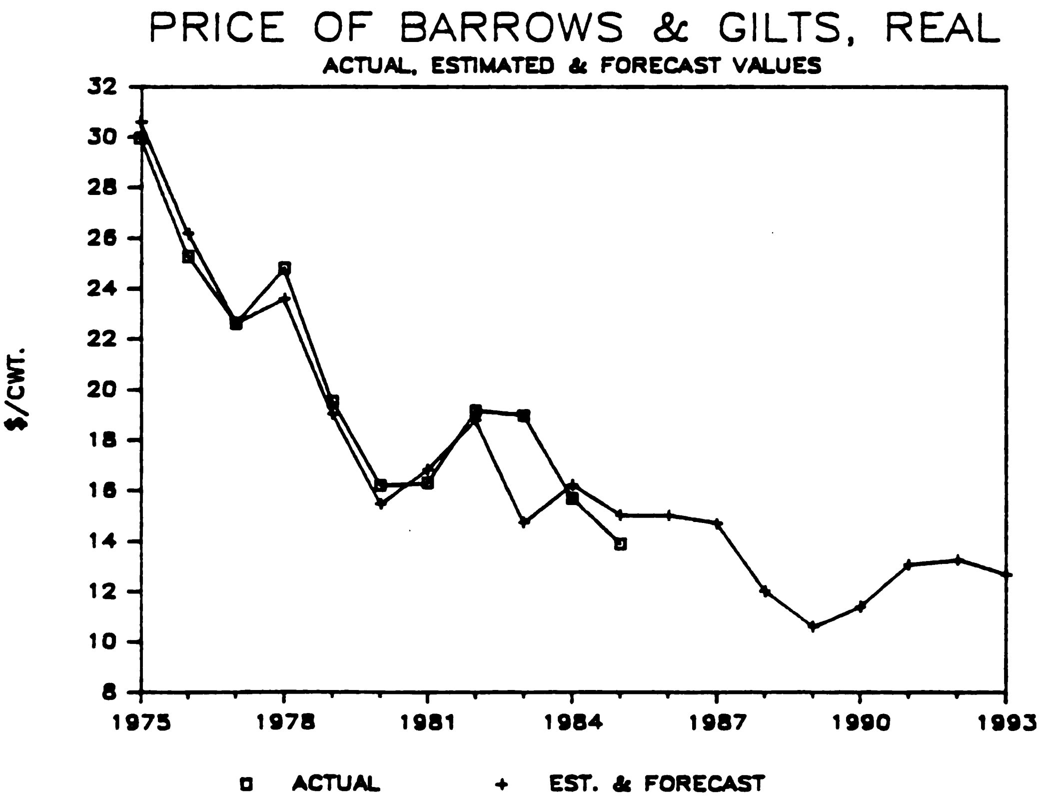

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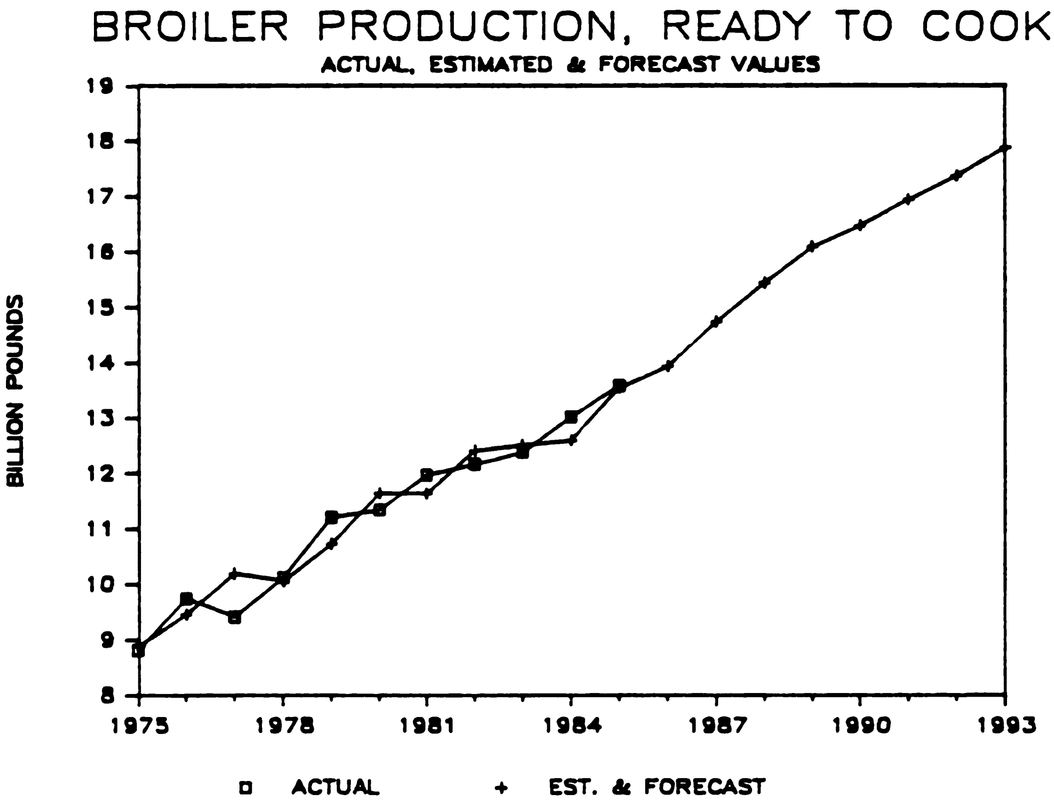

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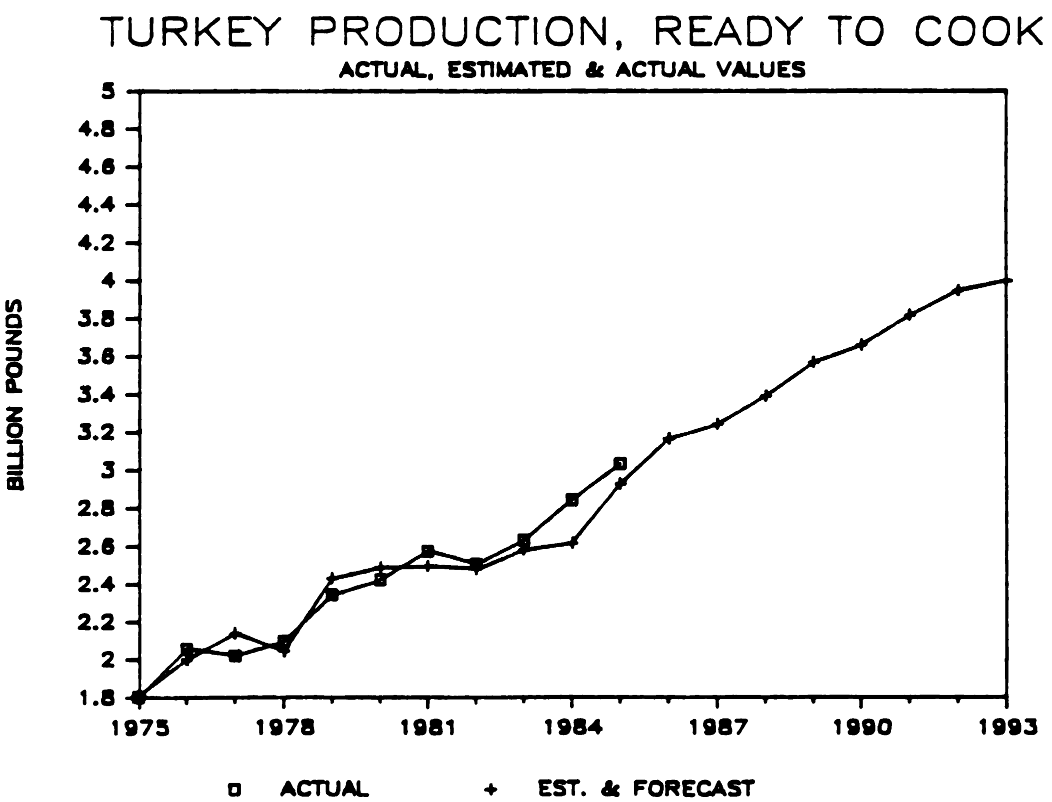


Figure 7.22

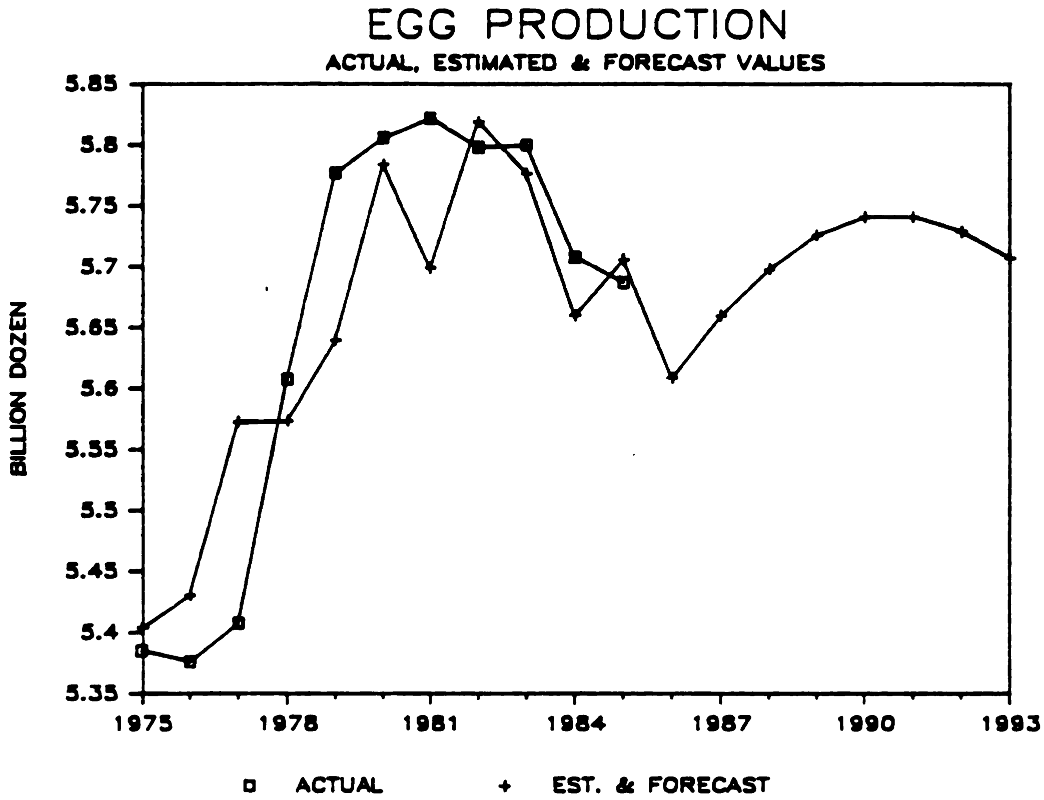


Figure 7.23

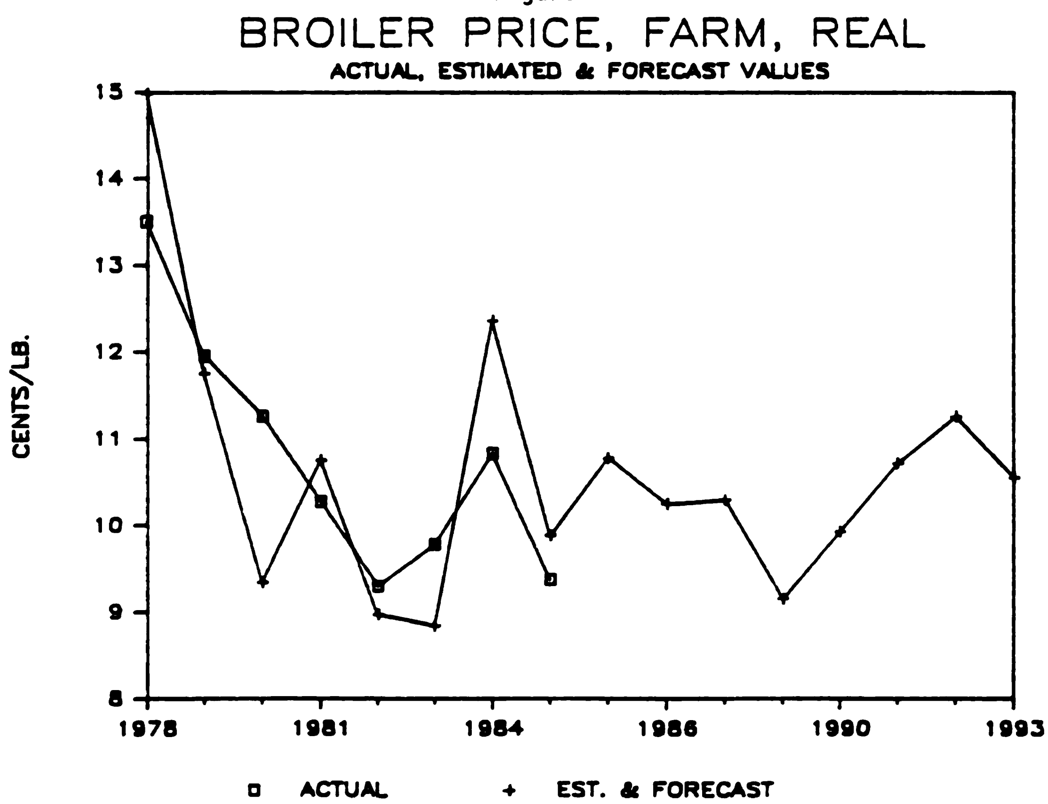


Figure 7.24

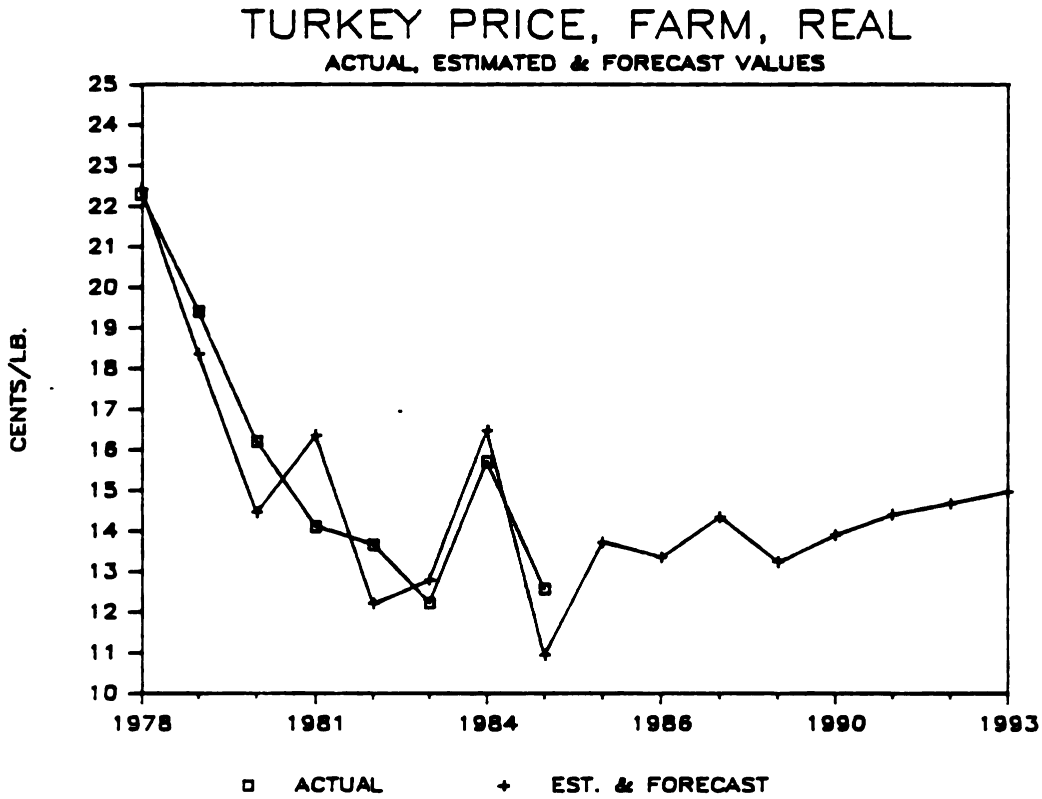
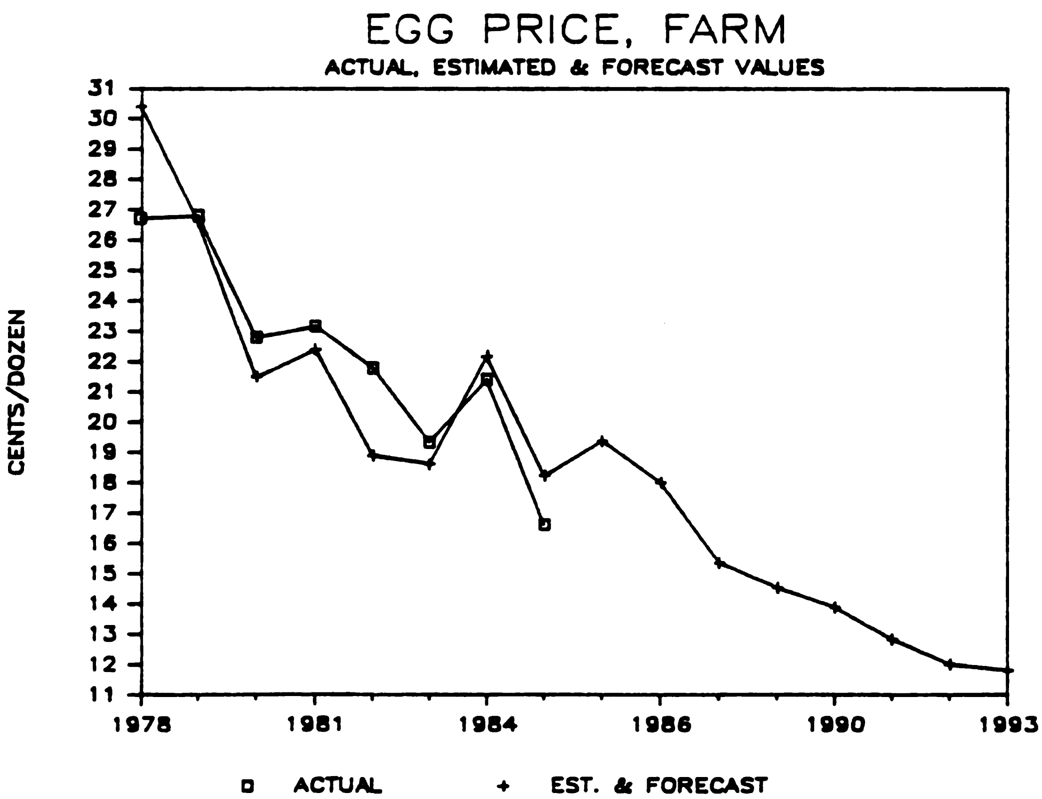


Figure 7.25



continue. However, sizable expansion projected to occur in poultry production will hold prices from increasing rapidly. Projected increase in production through 1987 will hold poultry prices near the projected 1986 levels.

7.6 Summary and Conclusions

The first stage of model validation is carried out by simulating the model as an integrated system over the historical period 1955-1985. In the historical simulation, historical values are supplied as initial conditions for the endogenous variables. Exogenous variables also take historical values. Prediction errors result from model misspecification and errors in parameter estimates. Absolute accuracy of simulated values are evaluated using statistical measures describing the differences between the simulated and actual values. Relative accuracy measures compares the simulated/forecast values with values from a naive no change model. The validation exercise is extended to include the ability of the model to simulate turning points in the data series.

Another area of model validation is the examination of model's sensitivity to initial period in which the simulation is started and changes in time paths of exogenous variables. Also, the model's ability to respond to stimuli in a way consistent with economic theory and empirical observation is evaluated. Based on yearly and average estimates of percent errors of simulated values, model2 of pork supply provided more accurate historical estimates. The results indicate more accurate price estimates from price models which allow parameter variation over time.

The model of pork supply which include the biological and physical relationships as restriction provided more accurate estimates compared to the base pork supply model.

CHAPTER 8

SUMMARY, IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The construction of policy and forecasting models that accommodate and track structural change in supply and demand relationships has been a challenge to model builders and practitioners. Rausser and Just (1981) pointed out that the ability of commodity models to admit structural change is one of the prerequisite for the achievement of global approximation accuracy.

The phenomenon of structural change in the U.S. demand for meat has been given attention by agricultural market analysts. While some rejected the occurrence of significant structural change in demand for meat in the U.S. (Moschini and Mielke, 1984; Hassan and Johnson, 1979), other analysts provided empirical support to the hypothesis of structural change in demand for meat, particularly for beef and poultry. (Braschler, 1983; Nyankori and Miller, 1982; Chavas, 1983; Cornell, 1983; Ferris, 1984; Hilker, et.al.,1985; Unnevehr, 1986). Empirical results from previous studies indicate that structural change in demand for meat began sometime in the mid 1970s.

This study extends the testing and analysis of structural change in demand for meat in the context of constructing a long-run forecasting model of U.S. livestock production and prices. The results of the preceding study provide further empirical evidence and support to the structural change hypothesis and suggest that such changes have continued into the 1980s.

The present chapter highlights the important aspects of the study. First, the methodology employed in testing for structural change is summarized in section 8.1. Section 8.2 provides a summary of the empirical results. Conclusions and implications of the results of the study are discussed in section 8.3. Finally, some recommendations for further research are discussed in 8.4.

8.1 Summary of Methods

The difficulties in empirically tracking changes in demand structure due to changes in consumer preferences have been recognized. The major problem is that shifts in the utility function are not directly observable. Given these difficulties, empirical attempts to identify structural change in meat demand by ad hoc procedures and varying parameter techniques have serious limitations. One of the criticisms pertains to the inability of these procedures to distinguish between structural change and model misspecification. That is, an observed shift in the demand parameters implies a structural change only if the model is correctly specified. Hence, an approach that is able to distinguish structural change and specification error is useful in empirical investigations of the hypothesized change in meat demand structure. Another approach is the identification and use of variables that explain shifts in the utility function. While theoretically attractive, severe data limitations usually prevent the application of this approach.

This paper explores the systematic use of several statistical procedures to minimize if not prevent the problems associated with ad hoc analysis of structural change. Specifically, the study uses a three-stage approach in investigating changes in the demand structure for beef, pork, broiler, and turkey meat. The approach is useful in detecting structural change as well as misspecifications in the context of simple models.

Meat demand models were constructed in the context of developing an annual forecasting model for livestock production and prices. On an annual basis, quantities of most meats in the market are predetermined given the lags in livestock production. Given the market level data and the predetermined quantities, the demand models are specified as inverse demand functions. That is, real market price is specified as a function of per capita quantity of commodity in question, per capita quantity of substitutes and complements, and real per capita disposable income (prices and income deflated by CPI).

The first stage of the analysis involves the estimation of inverse demand functions using recursive least squares for the period 1955-1985. In this stage, the recursive parameter estimates are used as a descriptive tool in determining the effects of individual observation in a sequential updating procedure. The pattern of the recursive estimates of coefficients of the inverse demand models are analyzed, taking note of particular trends and discontinuities. Plots of the recursive coefficients indicate the pattern of variation of individual parameters.

Statistical testing of parameter variation and specification errors constitutes the second stage of the analysis. In this stage, the statistics based on standardized recursive residuals introduced by Brown, Durbin, and Evans (CUSUM, CUSUMSQ, and Quandt's Log Likelihood Ratio) and those suggested by Dufour (location tests, Von-Neumann Ratio test, heteroscedasticity test) are used to test parameter variation and departures from the fitted functional form. Under the null hypothesis the demand parameters are stable over time and the recursive residuals have a zero mean and a scalar covariance matrix. That is, the recursive residuals are a normal white noise series.

A discontinuity in the demand parameters is expected to influence the behavior of the corresponding recursive residuals. For instance, an abrupt and sudden shift in the demand parameters at some point r^* in the sample period will result in an abrupt increase in the size of the recursive residuals and/or a tendency to overpredict or underpredict prices (the dependent variable) for $r > r^*$. A systematic shift in one or more of the demand parameters results in a systematic tendency to overpredict or underpredict.

The first two tests applied in the analysis were the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests which are based on the one-step ahead recursive residuals. With parameter variation, the standardized recursive residuals will have a non-zero mean and the CUSUM and CUSUMSQ can be used to test for structural change. If the plot of the CUSUM and CUSUMSQ crosses the confidence boundary, then the null hypothesis of constant parameters is rejected at the chosen significance level of 0.05. The non-parametric tests suggested by Dufour (1981) are also applied in the analysis.

The third stage of the analysis involve respecifying the model to include the information regarding the timing of the structural break indicated by the recursive residual analysis. Also gradual shifts in demand parameters are tested by augmenting the model with trend shifter variables. Other methods of allowing the parameters to gradually vary over time such as introducing Legendre polynomials are also used.

On the supply side, some aspects of structural change in livestock production is considered in respecifying the model of the U.S. beef and pork supply sector. In doing this, hypotheses concerning the likely effects of changes in biological, technical, and management technology on some key biological relationships surrounding hog production are considered. The trends in the physical relationships between stock and flow variables are introduced as restrictions in the specification of the beef and pork supply model.

8.2 Summary of Empirical Results

This section summarizes the major empirical results of the present study. The discussion is divided into three subsections to cover the results of the recursive residual analysis, the results of the alternative specifications of parameter variation in the inverse demand models for meat, and the results from the reestimation of the model of hog supply to capture the structural change in hog production.

8.2.1 Summary of Results of the Recursive Least Squares and Recursive Residual Analysis

The main results of the recursive estimation indicate that the parameters of the linear inverse demand model for beef, pork, and broilers show signs of systematic variation starting in 1977. The recursive residuals prior to 1977 in the case of beef and pork are very close to zero. After 1977, the recursive residuals are consistently negative. The results of the significance tests based on the standardized recursive residuals strongly reject the null hypothesis of constant parameters in the beef, pork, and broiler inverse demand models. Forward recursions indicate a tendency to overpredict prices of beef, pork, and broilers starting in 1977. The cumulative effects of the recursive residuals are indicated by the CUSUM plots which shows large overpredictions in the post 1977 period. The year 1977 is identified as the time of an important structural break in the demand for beef, pork, and broilers. No significant parameter variation is found in the inverse demand for turkey.

In the case of beef demand model, results of the recursive estimation declining and increasing trend (in absolute value) in the estimates of coefficients on the per capita beef quantity and poultry quantity respectively. The recursive estimates of the coefficient on real per capita disposable income appear to have slightly declined over the period. A discontinuity is evident starting in 1977 in the beef price equation as shown by the values of the standardized recursive residuals before and after 1977.

Recursive estimates of the pork demand model also indicate parameter instability. An increasing trend in the absolute value of the coefficient on pork per capita supply was evident during the 1965-1971 period. The coefficient then trended downward in absolute value until 1978. A tendency to overpredict pork prices starting in 1971 was evident in the pork demand model, reaching the two largest overpredictions in 1977 and 1984. The recursive estimates of coefficients of the broiler inverse demand model indicate a structural break in the market demand for broilers starting in 1977.

8.2.2 Summary of Results of Alternative Specifications of Parameter Variation in the Inverse Demand Models

The information on the timing of discontinuity in the parameters indicated by the recursive residual analysis is used in specifying the inverse demand models to explicitly account for the changes in demand parameters for the three commodities. The base demand model for each commodity is augmented by trend variables. One trend variable represents the trend from 1955-76 and another represents the turning point in the trend from 1977 to date. The trend variables are introduced to allow for gradual structural shifts in demand due to the hypothesized continous changes in tastes and health concerns. Since the model is linear in the variables, the coefficient on the time trend represents the rate of shift of demand in terms of annual prices given quantities and income.

An alternative specification allows for continous variation in the inverse demand parameters for beef, pork, and broilers by introducing Legendre polynomials in each of the parameters. Linear, quadratic, and cubic Legendre polynomial specification for the own quantity, quantity of substitutes, and income variables were tested. The corresponding own-quantity, cross, and income flexibilities were estimated and analyzed for each commodity. In general, the results indicate that the null hypothesis of constant parameters of the inverse demand models for the three commodities can be rejected at the .01 level based on the F-tests.

The own quantity flexibility for beef over time estimated from the Legendre polynomial models indicate flexible price response (i.e., own quantity flexibility is greater than one) to changes in beef quantity available for consumption, other factors held constant. The estimated income flexibilities for beef over time indicate a more than proportionate change in beef prices in response to a one percent change in real disposable income. As expected, the income flexibility estimates are positive. This is because prices move directly with changes or shifts in demand. A higher level of income is associated with a higher demand until a leveling off or saturation is reached where a certain percent increase in income will result in a less than proportionate increase in demand.

In contrast with the constant parameter inverse demand models for the three commodities, the varying parameter models with Legendre polynomials have better statistical properties. In particular, the Durbin-Watson statistics in the latter models indicates absence or reduction of serial correlation.

The third alternatiye specification allows for continous variation in each of the demand parameters by introducing Legendre polynomials and also for possible abrupt shifts or discontinuity in demand by using the information indicated by the recursive residuals analysis regarding timing of start of structural change.

Discrimination among alternative demand specifications is carried out based on the goodness-of-fit measures and relative parsimony characteristics. The Akaike Information Criterion and the Posterior Probability Criterion are employed to choose the most adequate specification of parameter variation.

Based on both criteria, any of the models which allows demand parameters to vary over time is superior to a constant parameter model. The results also show that the value of the log-likelihood function is larger for constant parameter price models which are estimated using more current time series data. Using data for all 31 years to estimate demand without accounting for parameter variation reduces the value of the log-likelihood function by more

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Based on both criteria, any of the models which allows demand parameters to vary over time is superior to a constant parameter model. The results also show that the value of the log-likelihood function is larger for constant parameter price models which are estimated using more current time series data. Using data for all 31 years to estimate demand without accounting for parameter variation reduces the value of the log-likelihood function by more than half.

The discrimination among the price models based on the goodness-of-fit and relative parsimony performance measures indicate superior performance of price models which allow gradual continous variation of the own-quantity and cross flexibilities and at the same time include an abrupt shift in demand sometime in the mid-1970s.

The estimated own-quantity flexibilities for beef from models with varying parameters exhibit an upward trend (in absolute value) during the whole period. A structural break is indicated by larger fluctuation in the own-quantity flexibilities for beef starting sometime in 1977.

The results indicate a significant positive response of meat prices to income changes. It is observed, however, that the relative magnitude of the income flexibility in the 1980s was lower than in the 1960s and early 1970s. The results also indicate increasing substitutability of poultry for beef as shown by the increase in the estimate of the cross-flexibility of beef with respect to poultry starting in mid-1970s.

The change in demand for beef appeared to result primarily from the shift in the relation between the price of beef and the consumption of broilers. Broilers has become a stronger substitute for beef beginning sometime in mid 1970s. Also, the change in health concerns of consumers as represented by the trend shifters is associated with the decline in beef demand.

The own-quantity flexibility estimates for broilers tended to increase (in absolute value) over the entire period. A discontinuity is apparent sometime in 1973 when the own-quantity flexibility declined. After the decline in 1973, a continuous upward trend in the own flexibility estimates remained during the late 1970s and through the 1980s. Prices of broilers has become more responsive to income changes as indicated by estimates of income-flexibility. The price of pork has become more responsive to changes in the supply of broilers and real income starting in mid-1970s.

8.3 Conclusions and Implications of the Study

Use of several statistical procedures suggest that structural change occurred about 1976-1977. While we can not be certain, we believe that structural change rather than model misspecification is the relevant explanation. Health concerns may be the cause but no sound data exists to permit testing this possibility. Given the current lack of data to permit analysis of specific causes of structural change, the three-stage approach offers some usefulness in determining the timing of change and pattern of variation in demand parameters.

A major conclusion of this study is the inadequacy of a constant parameter formulation for the demand for beef, pork, and broilers. Time varying parameter formulation of demand by using trend shifters and Legendre polynomials made a significant contribution over the constant parameter models. Trends and shifts in the U.S. market demand for meat have important implications for the meat industries. Evidence from the annual inverse demand analysis indicate that the shifts in demand are not only a result of changes in market variables (e.g.,quantities and income) but also due to non-market variables (e.g., changes in consumer attitudes toward meat and increasing diet concerns). Evidence of positive and high estimates of income flexibilities for beef, pork, and broiler imply a strong positive response of real prices to income changes. Future growth in real per capita disposable income can, therefore, be expected to continue to have significant positive effect on market demand for beef, pork, broiler, and turkey. The effects of non-market variables on as proxied by the time trend shifter variables indicate a negative impact of changing attitudes on market demand for beef and pork.

Estimation results indicate an increase in the absolute value of own quantity flexibility for beef, pork, and broiler. The higher own quantity flexibility imply a larger percentage change in real prices brought about by a one percent change in quantity supplied. The higher own quantity flexibility for the three meats has implications for price stability and price levels as the market structure change. Also, government programs on feed grains which indirectly affect livestock quantity, will now have a greater impact on meat prices.

The use of varying parameter models for analysis and forecasting provided more accurate projections over the sample period than did the base model. This was indicated by both relative and absolute accuracy performance measures. The contribution of varying parameter specification in estimating demand and supply models is substantial and promising. Other causes of structural change, such as changing income distribution and changing demographic characteristics of the population are not explicitly analyzed in this study. However, the results of the study regarding the timing and magnitude of parameter change should prove useful for forecasting livestock production and prices and for policy analysis.

By combining the information about the trends in physical and biological relationships in livestock production with economic variables in determining meat quantities, more accurate estimates of inventory and production are generated.

8.4 Recommendations for Future Research

The inverse demand models in this study are specified and estimated as single equation models. The single equation specification only allowed the imposition of the single inequality restriction which constrains the own-quantity effects on price to be negative. Chavas (1986) points out that there is a strong bias against finding evidence of structural change if it occured by using a single demand equation.

The demand system specification may be useful in further reestimation of the livestock model to examine structural change in demand. Under the demand system approach, testing of structural change involves the testing for the symmetry and negative semidefiniteness of the Slutsky matrix at all points. If the consumer preference function is not changing, these restrictions will be met at all points. If they are not satisfied, utility maximization is possible only if the preference function has changed. (Chavas, 1986, p.7). Chavas points out that this procedure has limitations because it assumes that the parametric form of demand correspond to the "true" demand function. The hypothesis being tested is actually a joint one, the theoretical restrictions and the null hypothesis regarding the functional form. The procedure does not allow the differentiation of the two hypothesis. The application of the non-parametric methods suggested by Chavas (1986) and Varian (1982) merit some interest in future examination of structural change. This approach does not involve the ad hoc specification of functional form, and hence one can separate out the hypothesis regarding the consistency of the data with the assumption of utility maximization by testing the symmetry and negative semidefiniteness of the Slutsky matrix.

Testing specific hypothesis regarding the cause of structural change offers advantages over the varying-parameter approach and may prove useful in future research in meat demand and reestimation of the livestock model. The present study provided some evidence that structural changes in market demand for meat can be attributed to both market (quantity and income) and non-market (changes in consumer attitudes towards meat and increasing health and diet concerns proxied by time trend shifter variables) factors. However, the time trend as a proxy for the non-market factors has severe limitations. A variable that captures consumers response to information regarding the ill effects of cholesterol may be tested. Combining available data with specific hypotheses about causes of structural change will be useful in understanding the recent changes in meat demand. Likewise, a more meaningful analysis of implications of such changes relevant to the meat industry can be drawn.

As a component of the MSU Agriculture Model, the livestock supply and demand model estimated in this study only generates projections of animal inventory, production, slaughter, and farm level prices for beef, pork, broiler, and turkey. The addition of a marketing-spread sector will be useful for further analysis of meat demand. This will allow the estimation of retail price data and consumer expenditures on meat. Analysis of structural change using retail level data can then be implemented using the MSUAM.

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APPENDIX

APPENDIX A

Data Used in the Estimations

obs	BFCOWT	FBEFQT	NFBFQT	NFBIMT	PORKQT	PKEX	PKIM	CHIKQT
1955	24966.00	9077.000	4491.000	229.0000	10027.00	154.0000	215.0000	3572.000
1956	24686.00	10007.00	4454.000	211.0000	10284.00	170.0000	186.0000	4217.000
1957	23876.00	9813.000	4388.000	395.0000	9579.000	177.0000	177.0000	4404.000
1958	23513.00	10025.00	3306.000	909.0000	9618.000	143.0000	234.0000	5005.000
1959	24434.00	10796.00	2797.000	1063.000	11131.00	174.0000	226.0000	5230.000
1960	25633.00	11561.00	3166.000	775.0000	10863.00	164.0000	222.0000	5144.000
1961	26589.00	12470.00	2830.000	1037.000	10730.00	162.0000	224.0000	5749.000
1962	27916.00	12345.00	2952.000	1440.000	11129.00	156.0000	256.0000	5789.000
1963	29763.00	13619.00	2809.000	1677.000	11863.00	242.0000	262.0000	6022.000
1964	31909.00	15002.00	3428.000	1085.000	12019.00	254.0000	313.0000	6195.000
1965	33400.00	14436.00	4263.000	942.0000	10736.00	149.0000	382.0000	6618.000
1966	33500.00	15637.00	4057.000	1204.000	11130.00	158.0000	430.0000	7198.000
1967	33770.00	16591.00	3593.000	1328.000	12377.00	164.0000	440.0000	7379.000
1968	34570.00	17172.00	3674.000	1518.000	12867.00	208.0000	462.0000	7422.000
1969	35490.00	17331.60	3795.000	1640.000	12774.00	260.0000	450.0000	7907.000
1970	36689.00	18201.00	3451.000	1816.000	13248.00	194.0000	491.0000	8465.000
1971	37878.00	18251.00	3619.000	1734.000	14606.00	198.0000	496.0000	8516.000
1972	38810.00	18865.00	3516.000	1960.000	13460.00	236.0000	538.0000	8887.000
1973	40932.00	17532.00	3707.000	1990.000	12578.00	279.0000	533.0000	8761.000
1974	43182.00	18887.00	4255.000	1615.000	13583.00	204.0000	488.0000	8915.000
1975	45712.00	17259.60	6413.400	1758.000	11314.00	317.0000	439.0000	8823.000
1976	43901.00	19932.06	5734.940	2005.000	12219.00	421.0000	469.0000	9751.000
1977	41443.00	19563.02	5422.980	1925.000	13051.00	399.0000	439.0000	9418.000
1978	38738.00	19426.74	4583.260	2322.000	13209.00	421.0000	495.0000	10129.00
1979	37062.00	17895.14	3365.860	2431.000	15270.00	448.0000	499.0000	11219.00
1980	37086.00	17639.65	3830.350	2085.000	16431.00	406.0000	550.0000	11357.30
1981	38726.00	18229.98	3830.350	1761.000	15716.00	452.0000	541.0000	11980.90
1982	39319.00	17952.03	4414.000	1939.000	14121.00	365.0000	612.0000	12174.70
1983	38081.00	18471.00	4589.000	1931.000	15117.00	219.0000	702.0000	12400.40
1984	37494.00	18280.00	5100.000	1823.000	14720.00	311.0000	954.0000	13031.70
1985	35370.00	19098.70	4749.000	1820.000	14721.00	268.0000	975.0000	13597.20

obs	BFPC	PKPC	POULPC	DINC	FBP	PPORK	CHP	TKP
1955	83.14902	60.79636	26.45678	2077.307	28.62843	21.88279	31.42145	37.65586
1956	86.86643	60.98175	30.63296	2121.622	26.94103	16.83047	24.07862	33.41523
1957	84.86836	55.69704	31.61922	2113.879	27.47331	20.71174	22.41993	27.75800
1958	81.42633	55.51743	34.55473	2108.545	31.25866	23.03695	21.36259	27.59815
1959	82.41579	62.88590	35.72513	2182.131	31.69530	19.19817	18.44215	27.37686
1960	85.80237	60.44689	34.92536	2183.765	29.19955	16.24577	19.05299	28.63585
1961	88.93740	58.75084	39.43579	2214.286	27.26563	19.15178	15.51339	21.09375
1962	89.72435	60.19685	37.97081	2279.250	29.71302	18.56512	16.77704	23.84106
1963	95.67115	62.79261	38.96070	2331.516	25.71428	16.77208	15.92148	24.31843
1964	101.6994	62.94264	39.85638	2457.481	24.12271	16.48009	15.28525	22.60495
1965	101.0844	56.45307	41.85731	2577.778	26.44444	22.55026	15.87302	23.49207
1966	106.3187	58.00773	45.13635	2679.013	26.45062	24.16667	15.74074	23.76544
1967	108.2572	63.67506	46.54475	2749.000	25.29000	19.37000	13.30000	19.60000
1968	111.4267	65.37423	45.00613	2826.295	25.78695	18.41651	13.62764	19.67370
1969	112.3295	63.96384	46.93675	2850.638	26.82149	21.59381	13.84335	20.40073
1970	114.4490	66.05641	49.71422	2902.837	25.24506	18.87360	11.69390	19.43250
1971	113.6660	71.77082	49.54228	2965.375	26.70239	15.21022	11.37675	18.21929
1972	115.9670	65.56580	51.43500	3068.635	28.55547	21.28492	11.25299	17.71748
1973	109.6178	60.55430	50.46506	3230.954	33.46356	30.25545	18.03156	28.70023
1974	115.7659	64.84330	50.67009	3159.783	28.36154	23.77793	14.55653	18.95735
1975	117.7508	52.95106	49.20522	3148.263	27.67370	29.97519	16.32134	21.58809
1976	126.9154	56.26161	54.16332	3212.317	22.93842	25.28446	13.54839	18.65103
1977	122.1900	59.43997	51.94811	3286.501	22.24793	22.62810	12.94766	19.55923
1978	118.3009	59.67608	54.93182	3388.434	26.78608	24.81576	13.51075	22.31320
1979	105.2720	68.07670	60.26660	3372.125	31.16375	19.54002	11.95952	19.41122
1980	103.4457	72.79187	60.52726	3254.457	27.13128	16.22366	11.26418	16.20746
1981	103.6390	68.76254	63.32244	3268.977	23.43268	16.31552	10.27749	14.11320
1982	104.7373	61.91582	63.26118	3243.514	22.24144	19.17503	9.304739	13.66309
1983	106.6856	66.59580	64.18000	3340.818	20.95174	15.98526	9.785523	12.23190
1984	106.6935	65.56152	67.11939	3621.544	21.06109	15.71061	10.76527	15.29582
1985	108.0840	66.32472	70.18650	3634.472	18.12733	13.86068	9.318886	14.86068

obs	TURKQT	EGGQT	SOWFST	SOWFFT	PPLS	PPLF	TPC
1955	818.0000	5407.000	8347.000	5599.000	6.900000	6.810000	95729.00
1956	957.0000	5500.000	7655.000	5181.000	6.940000	7.010000	178852.0
1957	1034.000	5442.000	7194.000	5112.000	7.120000	7.060000	262086.0
1958	1038.000	5442.000	7281.000	5887.000	7.050000	7.170000	374132.0
1959	1123.000	5542.000	7996.000	6128.000	7.080000	6.980000	496975.0
1960	1166.000	5134.000	6782.000	5839.000	6.960000	7.020000	529296.0
1961	1495.000	5202.000	7018.000	5918.000	7.180000	7.160000	648991.0
1962	1294.000	5297.000	6996.000	6098.000	7.080000	7.230000	748864.0
1963	1351.000	5292.000	7099.000	5987.000	7.150000	7.230000	846504.0
1964	1453.000	5435.000	6596.000	5525.000	7.230000	7.210000	875440.0
1965	1515.000	5463.000	5890.000	5006.000	7.220000	7.280000	868351.0
1966	1674.000	5517.000	6208.000	5810.000	7.320000	7.250000	1051236.
1967	1870.000	5777.000	6559.000	5901.000	7.340000	7.380000	1191684.
1968	1611.000	5680.000	6659.000	6130.000	7.370000	7.350000	1318170.
1969	1606.000	5629.000	6323.000	5745.000	7.360000	7.340000	1330140.
1970	1729.000	5704.000	7107.000	6876.000	7.330000	7.210000	1627424.
1971	1772.000	5806.000	7237.000	6339.000	7.170000	7.260000	1664708.
1972	1909.000	5742.000	6498.000	5973.000	7.310000	7.210000	1630368.
1973	1933.000	5503.000	6438.000	5869.000	7.160000	7.160000	1674337.
1974	1921.000	5468.000	6315.000	5476.000	7.090000	7.110000	1674880.
1975	1804.000	5385.000	4973.000	4952.000	7.140000	7.200000	1494906.
1976	2058.500	5376.000	5777.000	5850.000	7.300000	7.220000	1856690.
1977	2023.000	5408.000	6050.000	6009.000	7.100000	7.190000	1981726.
1978	2098.000	5608.000	6034.000	6398.000	7.040000	7.190000	2124288.
1979	2344.300	5777.000	7179.000	7306.000	7.040000	7.130000	2569800.
1980	2425.000	5806.000	7229.000	6829.000	7.230000	7.210000	2644720.
1981	2573.700	5822.000	6440.000	6258.000	7.390000	7.380000	2534031.
1982	2505.500	5798.000	5593.000	5810.000	7.340000	7.410000	2385292.
1983	2633.700	5655.000	6301.000	6176.000	7.520000	7.410000	2701495.
1984	2847.000	5708.200	5686.000	5856.000	7.450000	7.540000	2597580.
1985	3037.000	5687.100	5569.000	5667.000	7.640000	7.670000	2666186.

obs	BFCALF	CHIKLE	CORNPT	SOYMPT	POPUS	CPIT	FVAGET
1955	21.00000	1.550000	1.350000	2.630000	165.9310	0.802000	0.820000
1956	19.57000	1.420000	1.290000	2.370000	168.9030	0.814000	0.860000
1957	23.36000	1.310000	1.110000	2.670000	171.9840	0.843000	0.880000
1958	31.68000	1.210000	1.120000	2.790000	174.8820	0.866000	0.920000
1959	32.65000	1.090000	1.040000	2.780000	177.8300	0.873000	0.950000
1960	27.88000	1.000000	1.000000	3.030000	180.6710	0.887000	0.970000
1961	27.77000	0.910000	1.100000	3.180000	183.6910	0.896000	0.990000
1962	27.69000	0.850000	1.120000	3.560000	186.5380	0.906000	1.010000
1963	27.02000	0.770000	1.110000	3.550000	189.2420	0.917000	1.050000
1964	22.57000	0.690000	1.170000	3.610000	191.8890	0.929000	1.080000
1965	23.70000	0.660000	1.160000	4.075000	194.3030	0.945000	1.140000
1966	28.38000	0.590000	1.240000	3.940000	196.5600	0.972000	1.230000
1967	28.00000	0.540000	1.030000	3.850000	198.7120	1.000000	1.330000
1968	29.10000	0.490000	1.080000	3.710000	200.7060	1.042000	1.440000
1969	32.89000	0.430000	1.160000	3.920000	202.6770	1.098000	1.550000
1970	36.73000	0.400000	1.330000	3.930000	205.0520	1.163000	1.640000
1971	36.84000	0.360000	1.080000	4.510000	207.6610	1.213000	1.730000
1972	46.54000	0.290000	1.570000	11.45000	209.8960	1.253000	1.840000
1973	59.73000	0.260000	2.550000	7.315000	211.9090	1.331000	2.000000
1974	39.23000	0.220000	3.020000	6.540000	213.8540	1.477000	2.250000
1975	29.48000	0.200000	2.540000	7.390000	215.9730	1.612000	2.430000
1976	38.82000	0.160000	2.150000	9.990000	218.0350	1.705000	2.660000
1977	43.60000	0.140000	2.020000	8.210000	220.2390	1.815000	2.870000
1978	65.83000	0.137000	2.250000	9.500000	222.5850	1.954000	3.090000
1979	97.66000	0.135000	2.520000	9.090000	225.0550	2.174000	3.390000
1980	84.64000	0.120000	3.110000	10.91000	227.7040	2.468000	3.660000
1981	71.89000	0.120000	2.500000	9.120000	229.8490	2.724400	3.830000
1982	68.01000	0.120000	2.680000	9.360000	232.0570	2.891000	4.100000
1983	68.85000	0.110000	3.250000	9.410000	234.2490	2.984000	4.220000
1984	68.57000	0.110000	2.650000	8.500000	236.5740	3.110000	5.470000
1985	70.50000	0.103000	2.550000	9.200000	237.0000	3.220000	5.750000

obs	GRTS	GRTF	SLBGS	SLBGF	SSS	SSF	TSLHG	ADWHG
1971	2789.000	1884.000	44055.70	47709.41	2686.000	3157.000	96652.02	156.0000
1972	2975.000	2268.000	41335.68	42219.62	2303.000	2765.000	88946.82	159.0000
1973	2577.000	1921.000	38886.93	41445.62	2239.000	2304.000	85066.71	164.0000
1974	2475.000	1882.000	35648.91	37819.64	2257.000	3316.000	78587.73	166.0000
1975	1946.000	2162.000	36279.67	34460.22	1977.000	1946.000	74881.19	165.0000
1976	2319.000	1640.000	29111.14	32614.23	1505.000	2017.000	65265.42	166.0000
1977	2700.000	2128.000	35468.05	39565.71	2023.000	2212.000	79378.26	170.0000
1978	2242.000	2787.000	38785.32	37930.16	2008.000	2073.000	80503.81	171.0000
1979	2728.000	2169.000	38740.73	43076.42	1965.000	2882.000	86935.36	172.0000
1980	2411.000	2553.000	44675.66	45398.69	2585.000	2870.000	95466.23	171.0000
1981	1557.000	1949.000	45387.98	41505.50	2347.000	2464.000	91554.78	173.0000
1982	1752.000	2017.000	40155.65	37540.60	2176.000	2021.000	81794.63	173.0000
1983	2488.000	2020.000	37873.86	40753.64	1850.000	2742.000	83473.77	173.0000
1984	2093.000	1884.000	42680.98	40799.00	2083.000	2355.000	87954.78	173.0000
1985	1982.000	1892.000	38491.19	38785.60	1918.000	2109.000	80806.23	174.0000

obs	P1	P2	P3	DVT73	DV73ON	DV77ON	DVT77	DVT80
1955	-1.000000	1.000000	-1.166667	0.000000	0.000000	0.000000	0.000000	0.000000
1956	-0.933333	0.806667	-0.768099	0.000000	0.000000	0.000000	0.000000	0.000000
1957	-0.866667	0.626667	-0.435901	0.000000	0.000000	0.000000	0.000000	0.000000
1958	-0.800000	0.460000	-0.165333	0.000000	0.000000	0.000000	0.000000	0.000000
1959	-0.733333	0.306667	0.048346	0.000000	0.000000	0.000000	0.000000	0.000000
1960	-0.666667	0.166667	0.209876	0.000000	0.000000	0.000000	0.000000	0.000000
1961	-0.600000	0.040000	0.324000	0.000000	0.000000	0.000000	0.000000	0.000000
1962	-0.533333	-0.073333	0.395457	0.000000	0.000000	0.000000	0.000000	0.000000
1963	-0.466667	-0.173333	0.428988	0.000000	0.000000	0.000000	0.000000	0.000000
1964	-0.400000	-0.260000	0.429333	0.000000	0.000000	0.000000	0.000000	0.000000
1965	-0.333333	-0.333333	0.401235	0.000000	0.000000	0.000000	0.000000	0.000000
1966	-0.266667	-0.393333	0.349432	0.000000	0.000000	0.000000	0.000000	0.000000
1967	-0.200000	-0.440000	0.278667	0.000000	0.000000	0.000000	0.000000	0.000000
1968	-0.133333	-0.473333	0.193679	0.000000	0.000000	0.000000	0.000000	0.000000
1969	-0.066667	-0.493333	0.099210	0.000000	0.000000	0.000000	0.000000	0.000000
1970	0.000000	-0.500000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1971	0.066667	-0.493333	-0.099210	0.000000	0.000000	0.000000	0.000000	0.000000
1972	0.133333	-0.473333	-0.193679	0.000000	0.000000	0.000000	0.000000	0.000000
1973	0.200000	-0.440000	-0.278667	73.00000	1.000000	0.000000	0.000000	0.000000
1974	0.266667	-0.393333	-0.349432	74.00000	1.000000	0.000000	0.000000	0.000000
1975	0.333333	-0.333333	-0.401235	75.00000	1.000000	0.000000	0.000000	0.000000
1976	0.400000	-0.260000	-0.429333	76.00000	1.000000	0.000000	0.000000	0.000000
1977	0.466667	-0.173333	-0.428988	77.00000	1.000000	1.000000	77.00000	0.000000
1978	0.533333	-0.073333	-0.395457	78.00000	1.000000	1.000000	78.00000	0.000000
1979	0.600000	0.040000	-0.324000	79.00000	1.000000	1.000000	79.00000	0.000000
1980	0.666667	0.166667	-0.209876	80.00000	1.000000	1.000000	80.00000	80.00000
1981	0.733333	0.306667	-0.048346	81.00000	1.000000	1.000000	81.00000	81.00000
1982	0.800000	0.460000	0.165333	82.00000	1.000000	1.000000	82.00000	82.00000
1983	0.866667	0.626667	0.435901	83.00000	1.000000	1.000000	83.00000	83.00000
1984	0.933333	0.806667	0.768099	84.00000	1.000000	1.000000	84.00000	84.00000
1985	1.000000	1.000000	1.166667	85.00000	1.000000	1.000000	85.00000	85.00000